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Developing Mobile Health Information Systems for the Global South

Development of an emerging Android platform

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Abstract

Fragmentation of health information systems is a common issue in the world today. Aid agencies and other organizations that seek to resolve a problem in developing countries often introduce their own vertical systems which do not help the decision makers in a country. This thesis sets out to explore the theoretical ideas that can be utilized to understand the development process of an integrated mobile health information system in the Global South. Further it seeks to address how such a system can address the needs of the users at the lowest level, contribute to organizational growth and support users at other locations. In this study I will present a case in Zimbabwe where a mobile health information system was developed and therefore seek to identify the challenges encountered and the strategies used for resolving them.

The empirical work of this thesis reduces fragmentation of the health information system in Zimbabwe and limits the need for manual processes. The main contribution was to develop an Android application for data collection, which is integrated with the national health information system in Zimbabwe, DHIS2. The application was set out to improve the pre-existing system for malaria disease surveillance in an ongoing pre-elimination programme in the province Matabeleland South. However, as the project grew, a standardized data collection application emerged aimed at a national roll-out in Zimbabwe, but also targeted internationally to support others in the DHIS2 community.

The findings of this study show that utilizing the design-reality gap model and its three aspects of participative methods, rapid prototyping and observational techniques, and in addition utilizing local "hybrids" that work with the pre-elimination programme and have a technical understanding is a good approach. This study concludes that such utilization of the design-reality gap model has been successful. Further, the findings suggest that it is important to fulfill user requirements while on the other hand making decisions to support organizational growth such as moving to the Android platform. The development of the standardized application opens up to the risk of the project moving away from the malaria pre-elimination use-case, therefore a Zimbabwean software development company was engaged in the development process. This study concludes that such an utilization of the design reality gap model has been successful. Further, this study concludes with that moving to the Android platform was necessary for organizational change.

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Chapter 1

Introduction

1.1 Background

It is not easy to develop health information systems (HIS) and especially not in developing countries. Heeks (2006) notes that there are more failures than success stories in HIS development in developing countries.

In developing countries, shortage of skilled staff to develop, maintain and utilize such ICT systems is a common challenge. It is therefore often necessary to employ external actors and get support from international donor agencies to help strengthen the HIS. When outsourcing the development to external actors, a common challenge is that system designers fail to understand the context in which the system is being implemented (Heeks et al. 2003). Some developing countries today can be characterized by poor infrastructures such as unstable power and poor Internet connection (J. Braa, Monteiro and Sahay 2004). Usage of external actors that do not recognize these limitations can lead to large gaps between system design and usage of the system. Sometimes it can be a problem when external actors have their own agenda, or vested interest, in the generated information. Furthermore when developing a new HIS it is important that it can communicate and share the information, thus avoiding vertical silo systems. It is thus important that the information flows through the national HIS to help decision makers make the correct choices.

In this thesis we will look at which theoretical approaches we can utilize to understand the development process of mobile HIS in developing countries. The theoretical approach of the design reality gap model from Heeks (2002) will be central in this study. In this study it has been found that the critique offered by Heeks (2006), which states that the dimensions of the model should not have a static view was found to be legitimate. Other theoretical approaches, such as flexible standards and the concept of innovation will be presented to see if they can address the ever-changing environment for a scaling ICT system. The concept of innovation will be used as a metaphor to describe the process of innovation of an IT artifact while trying to get more users to use the system. Further, this thesis will include

a case which describes the development process of Android applications¹, that works as an extension to the national HIS in Zimbabwe. The Android application is targeting the issue of malaria and is built to support the work flow of an Environmental Health Technician (EHT) who works at health facilities in Zimbabwe. However, as the project has evolved, an increasing focus on standardization has occurred to support different disease programmes and to make the technology apply in different contexts.

Zimbabwe has recently introduced the District Health Information System 2 (DHIS2) as their main HIS. The software was rolled out to all districts and they have a long term plan to introduce it to all health facilities. DHIS2 is a web based HIS that is used across 47 countries in the world and is still growing. DHIS2's core is developed at the University of Oslo with several full time developers, but also software developers located around the globe such as in Asia and Africa. The DHIS2 software is developed with open source technologies and it is a generic software that is free to install and run. However, it requires several technical skills to do so.

Today, Zimbabwe use some mobile health information systems for data collection. They have adopted the FrontLine SMS² system, which is used for weekly data reporting. It was implemented by a non-governmental organization, *ZimHISP*. FrontLine SMS is a open source J2ME system, working on low-end phones, that allows the user to enter and submit data reports. *ZimHISP* distributed one mobile phone with the software to each health facility for reporting on diseases such as diarrhea, malaria, influenza, snake bites etc. The system use either GPRS or SMS for data transmission to the server. The MOHCC has stated that FrontLine SMS has been a successful implementation that is used across Zimbabwe, and the fact that it is able to communicate with DHIS2 makes it successful. The DHIS2 mobile browser based application³ is also available for use when the desktop version is not an option, however it is not being widely used. In addition to this, for Malaria surveillance, they use a Personal Digital Assistant (PDA) for data entry when registering, following up or doing a contact screening of a malaria patient. The PDA's is based on the paper-based system for Malaria surveillance, but contains a much more compressed version of the data entry forms which is specifically designed for devices with small screens.

During the project period I have developed Android applications for Malaria surveillance, which utilize the strengths of an application based approach including a database that enables offline storage of data. The Android applications, just like the PDA's, included a compressed version of the data entry forms from the National Malaria Control Programme (NMCP). The Android application is able to communicate with the Zimbabwe's national DHIS2 instance by utilizing its application programming interface

¹<http://developer.android.com/about/index.html>.

²<http://www.frontlinesms.com/>.

³<http://apps.dhis2.org/demo/light/index.action>.

(API) for direct communication with the server.

This project was conducted within an Action Research framework over a period of 18 months and the development has gone through four cycles.

1.2 Motivation

I have always been interested in computers and IT systems, so my personal goal has been to develop an ICT system that someone uses and really appreciates. I felt that a master's program in Informatics: programming and networks would give me the opportunities to learn about this. During the masters program I chose a lot of different courses such as IT management, language processing and algorithms. However, the course that made the most impact on me personally, was the Open source software programming (INF5750). This course introduced me to the research group Global Infrastructures (GI)⁴ and the DHIS2 software. I found it very interesting to see how GI worked across the globe implementing HIS in developing countries, and I felt that this was my chance to make something usable. After taking a course in Android application development in my B. Sc in Computer Engineering at Oslo University College, I was really interested in combining Android applications and DHIS2 software. Therefore I started looking for mobile projects within the GI group and research topics such as open source development and sustainability of IT systems that generated most interest. After reading up on some of the existing literature on these topics, the Design-reality gap model captured my interest. This model is a pretty generic tool that I think would work in several contexts and now I was curious to find out how it is possible to reduce the gaps. To understand this, I had to read literature on developing countries to understand their context of where the system is going to be used.

1.3 Context of Study

1.3.1 Deciding on the Zimbabwe project

In the fall of 2013 several meetings were held for those who were interested in doing a master thesis for the GI group. I was looking at several different projects and especially those which contained mobile technology or included map technology. I got introduced to a interesting project in the Gambia where they were trying to utilize GPS coordinates for their data warehouse. Another project also emerged and the Zimbabwe project was also brought to my attention. My supervisor told me that this project had more political support than the project in the Gambia, thus it was bigger chance for making something that is being used. An overview of the Zimbabwe project is presented below.

⁴<http://www.mn.uio.no/ifi/forskning/grupper/gi/>.

1.3.2 Overview of the project

The Zimbabwe project was seeking to improve the installed base for Malaria pre-elimination in the Matabeleland South Province and some additional districts. Installed base can loosely be defined as the existing infrastructures in a given context (Hanseth 2002). Installed base can be both technical and non-technical infrastructures, the former includes such as Internet, devices and software, where the latter includes such as roads, electricity and buildings.

The main practical contribution of this project was to develop the Android application for Malaria surveillance. The Android application is based on the installed base for malaria surveillance system and thus it was necessary to get a proper understanding of it. For that reason two field trips to Zimbabwe were conducted.

However, it all started with customization of the Malaria forms inside DHIS2. The MOHCC had provided a document showing all the different paper-based forms in the National Malaria Control Programme (NMCP) which were customized into DHIS with the original design. The customization included changes such as utilizing DHIS2's functionality to reduce duplication of data. Simultaneously, without knowing it, the MOHCC had started working on a new set of forms that were much more compressed and which included questions that required less text and more yes and no answers. These new compressed forms were specifically tailored for the PDA system that was rolled out in 2014. I did not find out that these forms existed before the first field trip to Zimbabwe in August of 2014. The first visit to Zimbabwe included a four week internship at a local software development institution, the Health Informatics Training and Research Advancement Center (HITRAC), which is located inside the University of Zimbabwe College of Health Sciences in Harare. Here the prototype of the Android application was finalized with a main goal to generate interest from any stakeholders. A second goal was to get some technical contributions from any software developers at HITRAC. The first field trip was successful, however with one goal achieved. It was generated interest from stakeholders, but technical contributions from HITRAC were not possible at the time.

After returning home to Oslo from the first field trip, it was brought to my attention that a DHIS2 Mobile Team had started working on a DHIS2 Android software development kit (SDK). The SDK was four months into the development phase when it was discovered. Along with the SDK, it provided an example Android application that utilized the SDK for communicating with a DHIS2 instance. The problem with this application was that the Mobile Team did not have any real case for development thus they had been developing without concrete specifications. Development of the SDK was aimed at lessening the code for future developers through the implementation of trivial methods. However, the problem was that it was not nearly complete and still much functionality was missing, especially in order to match specifications of the Zimbabwe malaria project. On the other

hand, migrating to the SDK would make it easier to create a flexible application that was able to support newer versions of DHIS2, even after this master project had ended. Therefore the decision was taken to migrate the use case from the malaria project into the SDK example application ('DHIS2 Tracker'). The DHIS2 Tracker project was branched and further developed with the specifications from our use case which included functionality, such as offline functionality, enrollment to programs and possibility to add new program stages to a person. About a month in the developing phase, collaboration with the DHIS2 Mobile team had started and they started to contribute some code to the Zimbabwe project branch. The DHIS2 Mobile Team software developers were based in the Philippines and in Vietnam so it was challenging to collaborate, but it did ensure double shift development because of the time difference.

In February 2015, the Zimbabwe DHIS2 Tracker was ready for a pre-pilot with full offline functionality and with most of DHIS2 tracker functionality, just as in the web application. Therefore another field visit to Zimbabwe was necessary to conduct the pre-pilot of the application and parallel improve the understanding of the installed base. The pre-pilot and our improved understanding generated a lot of constructive feedback which was put into the application for pilot in June.

Simultaneously with the second field trip, the decision to standardize the Zimbabwe DHIS2 Tracker was taken by the mobile team at the University of Oslo. There was now an increasing focus on standardization because several new actors had expressed their interest in the project. Among the interested actors were countries such as South Africa and Namibia. The Zimbabwe DHIS2 Tracker had combined surveillance for malaria patients and for malaria breeding sites. The standardization process divided the Zimbabwe DHIS2 Tracker into two separate Android applications; Tracker Capture and Event Capture.

1.4 Research Aim and questions

Foster and Heeks (2013) highlights the need of conceptualizing diffusion and innovation of an IT artifact. Foster and Heeks (2013, p. 297) note that "*work specifically on scaling of ICTs for emerging markets is lacking*". Therefore, this thesis will seek to understand challenges between user needs at local level and at the same time innovating to allow the system to grow and support users at other locations.

As previously stated, there are more failures than success stories within the literature on developing HIS for developing countries. For that reason this thesis will identify the encountered risks within the development of a Malaria pre-elimination system in Zimbabwe. In the development process it encountered some tensions when trying to scale the project, therefore this study will seek to resolve these tensions between innovation and diffusion. The research questions can be summarized as presented below:

- What theoretical ideas can be utilized to understand the development process of a mobile Health Information System in a country in the Global South?
- How can we understand the challenges of meeting user needs at the lowest level and support innovation for system growth to support users at other locations?
- In the case of Zimbabwe, what challenges arose and what strategies were used to address them

In the next section I will present what theoretical approach that this study utilized.

1.5 Theoretical Approach

I have targeted literature which is focused on IT in developing countries for trying to understand what makes IT projects succeed and fail in this context. Here I got interested into the Design-reality gap model as described by Heeks (2002). I want to see how we can reduce the gaps in order to make the system more likely to succeed. Further this study will utilize the concept of innofusion for exploring how the tensions can be resolved when scaling an ICT system. There are no identified cases that utilized these theoretical approaches when developing in the global context. The practical contribution of this thesis included the development of Android applications. This is noted in the next section.

1.6 Empirical Approach

This study has been conducted within an Action Research framework and the empirical work has gone through four cycles. The four cycles are listed below

- Customization of NMCP's forms and to see if it was feasible in DHIS2 with keeping it original design.
- Development of the Android prototype application.
- Development of the Zimbabwe DHIS2 Tracker which is based on the DHIS2 Android SDK and a sample application provided along with the SDK.
- Standardization of the Zimbabwe DHIS2 Tracker and dividing the use case into two Android applications; Tracker capture and Event Capture

These four Action Research cycles generated a lot of data, and an overview of the findings is presented below.

1.7 Overview of Findings

The findings are divided into two parts; theoretical findings and empirical findings. In the theoretical findings, it was found that there is a tension in the concept of innofusion between innovation and diffusion. It was discovered tensions when trying to make the system scale to more users. Further, the critique of the design reality gap model from Heeks (2006) which states that the dimensions of the model should not have a static view was found to be legitimate.

In the empirical case, a strong culture of information usage at the health facility level was found. However, at higher levels, such as District level, information was not very much used. Further, competent technical people were found in the non-governmental organization HITRAC. Usage of mobile technology was found to be very common in Zimbabwe. Furthermore, usage of Android devices was found to be widespread. When visiting a rural health facility, an EHT had a seven inch Android tablet for his own personal use.

A more thorough discussion of the findings is presented in chapter 6. The rest of the thesis is structured as noted in the next section.

1.8 Structure of Thesis

Chapter 2: Research context. In this chapter I will describe a detailed background of Health information systems and mobile interventions. I will also provide a background story about the HISP project and the history of DHIS

Chapter 3: Theoretical literature. This chapter will cover the relevant theoretical literature which is used in this study. The concepts and models will be discussed and how they were relevant.

Chapter 4: Research Methods. This chapter will cover the research method that is used, how it is used and in which perspective my work is in.

Chapter 5: Research case. Here I will provide a detailed background of Zimbabwe and I will present my contributions.

Chapter 6: Discussion and findings. This chapter will cover a discussion of the findings and it will be closely linked to the relevant literature, as presented in chapter 2 and the theory that is presented in chapter 3.

Chapter 7: Conclusion. This chapter will contain conclusive remarks and a note to any future work.

Chapter 2

Research context

In this chapter I will describe what literature my thesis is based on. First I will describe what a Health Information system is and what kind of challenges often occurs in developing countries, but also identify its advantages and which possibilities it creates. Following this, I will go into what mobile projects are being used and how they are used. Further I will present a background of the HISP project and evolution of the DHIS software. Finally I will present the different solution types of a mobile HIS and the Android platform.

2.1 Defining a Health Information System

A health information system's goal is to provide good quality of data to support and improve decision-making at every level of a organization (Lippeveld, Sauerborn and C Bodart 2000). Lippeveld, Sauerborn and C Bodart (2000) specifically states that a health information system can be defined as *"a set of components and procedures organized with the objective of generating information which will improve health care management decisions at all levels of the health system"* (Lippeveld, Sauerborn and C Bodart 2000, p. 3). Drawing from the definition above, we can say that a health information system is an information system within the area of health that seeks to improve decision making. Practically speaking, this study includes use of systems such as a Routine Health Information System (RHIS) and a programme specific individual record system (Lippeveld 2001).

In this study the HIS collects aggregate data and presents the information in a palatable way using graphs and charts for easier decision making, as well as collecting individual patient records. A programme specific individual record system includes a series of data elements that are collected. An example of such a HIS can be a surveillance system for maternal mortality. Such a system is targeted to collect patient specific data such as name, age and reason of death. An aggregated HIS can not deal with this patient specific data so programme specific individual record system need to aggregate data to create indicators. A reported indicator can be number of deaths based on age. In this study I am focusing on how these two aspects

of health information systems can communicate.

2.1.1 Health Information system challenges in developing countries

AbouZahr and Boerma (2005, p. 582) argue that *“it is not because countries are poor that they cannot afford good health information; it is because they are poor that they cannot afford to be without it”*. HIS in development countries can often be characterized by fragmentation, poor infrastructure and poor information usage (J. Braa, Monteiro and Sahay 2004). Fragmentation is created by many vertical systems that are individually funded by donors. To deal with the challenge of fragmentation, J. Braa and Sahay (2012, p. 2) raise the question *“A key challenge we focus on is “how can systems can speak to each other – both technologically and institutionally”*”. Systems that do not communicate with each other is seen as a common problem. Information generated in one system can be useful for another systems, but they need to communicate together. J. Braa, Hanseth et al. (2007) argue that fragmentation entails poor data quality. Poor data quality is influenced by how data is collected, compared and analyzed (Stansfield et al. 2006). Further, Shrestha and Claude Bodart (2000) note the following factors that have an impact on poor data quality:

1. Failure to report data
2. Reporting of inaccurate data
3. Intentional reporting of false data
4. Failing to process data
5. Delaying the reporting of data

Poor information usage for decision making by managers is also a frequent challenge. Garrib et al. (2008) highlight that there may be several reasons for poor information usage. In developing countries there is often a poor tradition for information usage at facility level and even by the managers (Garrib et al. 2008). If the data that is collected is of poor quality, managers are not able to make use of the data. Because of high workload on senior staff, the data collection task is often given to the less experienced health workers that may lead to poor data quality because of their lack of understanding of possible errors (Garrib et al. 2008).

2.2 Integrated Health Information System

As mentioned above, fragmentation of health information systems is a major challenge. To cope with this challenge, a greater deal of integration between the different health information systems is needed. J. Braa and Sahay (2012) suggest the usage of data warehouses to gather data from different sources. Further they define data warehouse as a *“database which*

contains and manages data of different types from varying sources; and which on the data output side, is designed to process and present the data and provide a multiplicity of users with data, which is tailored for their specific needs" (J. Braa and Sahay 2012, p. 22). World Health Organization et al. (2008) specifies that an integrated data warehouse (they use the term data repository) should:

- Keep data from different sources
- Exist in multiple locations so that the data is safe
- Record quality information and history of data sets
- Collect, manage and distribute information for both national and international actors

Usage of data warehouses can therefore improve decision making for managers when information from different health information systems is gathered and presented. An example of better decision making may be the distribution of health care equipment or human resources if there is a disease outbreak.

2.3 Integration versus Interoperability

Integration is seen as making the two systems speak the same languages in the simplest way. The system that is integrating into "the larger one", needs to follow that system's language and structure for sending and receiving data.

Interoperability is rather more complex. For systems to be interoperable, it requires that devices and systems can work together in real time in order to present data from all components¹. Interoperability would also require that data is stored in one database (System A), and the data is accessible for system B, but system B does not store the data².

A key difference between these two terms is that integration is when a system is designed to communicate with another system. Interoperability is when two independent systems that were not designed to communicate together, communicate over shared standards³.

2.4 Mobile projects

Mobile technologies "*enable data reporting from remote outreach areas previously not accessible for computerisation*" (J. Braa and Sahay 2012, p. 1). Mobile devices has seen a rapid growth since introduction (Sanner, Roland and K. Braa 2012). In 2002, subscriptions of mobile lines

¹<http://blog.capsuletech.com/integration-vs-interoperability-more-than-a-matter-of-semantics>.

²<https://www.dhis2.org/doc/snapshot/en/implementer/html/cho7.html>.

³https://www.ibm.com/developerworks/community/blogs/woolf/entry/interoperability_vs_integration?l

exceeded the number of fixed lines world wide (Kaplan 2006). Rashid and Elder (2009, p. 1) states that “*most of the countries in the developing world have skipped fixed-line infrastructure and leapfrogged directly into mobile technology*”. Sanner, Roland and K. Braa (2012, p. 155) note that “*The extensive and swift roll-out of mobile telecom infrastructures has triggered an avalanche of health related digital innovations, commonly referred to as mHealth, encompassing all kinds of mobile devices from wireless chipbased solutions to portable computers*” . Further, Sanner, Roland and K. Braa (2012) note that there are several technical solutions where mobile phone technology can be applied:

- Interactive Voice Response (IVR)
- Plain text SMS (without an installed application)
- Mobile Applications with
 - SMS transport of data
 - GPRS transport of data
- Browser based solution

and Sanner, Roland and K. Braa (2012) places them in a matrix with the dimensions flexibility, robustness and usability. Usability is represented through size of the bubbles in the figure 2.1 below.

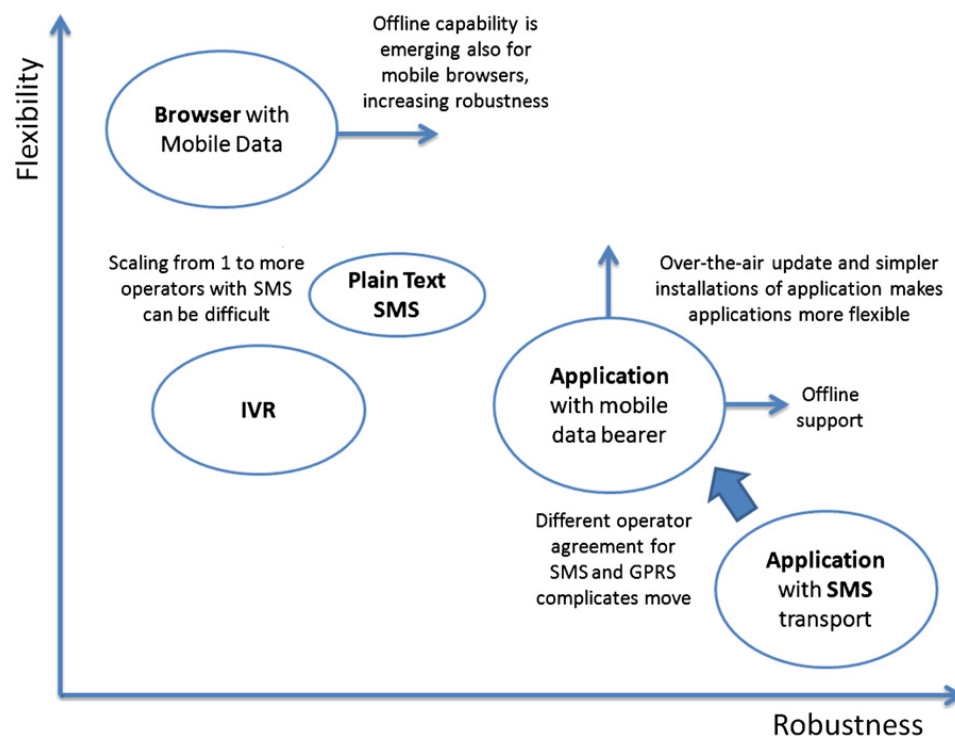


Figure 2.1: Matrix of robustness and flexibility from the different mobile phone technologies (Sanner, Roland and K. Braa 2012, p. 162).

Ideally, a solution in the top right corner would be the best solution. However, each solution has some additional concerns such as infrastructure, cost and usability (Sanner, Roland and K. Braa 2012). In developing countries today there exists numbers of mHealth projects that utilize the solution types presented above. Different environments and projects require different solution types to be successful. IVR may be successful if health care personnel has low literacy, plain text sms is beneficial for aggregate data reporting on low end phones, browser solutions are effective if Internet connection is available and application based solutions may be a good choice if proper devices and technology exist.

2.5 Health Information Systems Programme

The Health Information Systems Programme (HISP) is a global network that is established and based at the University of Oslo. It was initiated after the apartheid regime in South Africa in 1994 to rebuild the health care system. In the following years they targeted developing countries to help them implement computer based health management information systems. HISP has introduced the DHIS software to 47 countries and is dominant in Africa, but is also in Asia and Latin-America. HISP has partnered with local organizations, universities and ministries of health in several countries in Africa and south-east Asia⁴.

2.6 DHIS

HISP has since 1994 been developing the District Health Information System with developers around the globe. DHIS is a *“tool for collection, validation, analysis, and presentation of aggregate and transactional data, tailored (but not limited) to integrated health information management activities”*⁵. DHIS is built on open source technologies, is released under the BSD license and thus is free to install, use and modify. A general idea about the DHIS is that it should be easy to customize. Users of the system should easily be able to add health facilities to the system or change data elements in a form. Now I will present the history behind the DHIS.

2.6.1 DHIS (version 1)

It all started in South Africa where HISP helped rebuilding the health care system after the apartheid regime that had dominated the country since mid 20th century (J. Braa, Monteiro and Sahay 2004). The DHIS1 database was built on Microsoft Office Access 97/2000 because it was the *defacto* standard at that time. It was developed using participatory design principles, interacting, testing and collaborating with the users to ensure them the information they needed to optimize their work environment⁶.

⁴<http://www.hisp.org/about/index.html>.

⁵<https://www.mn.uio.no/ifi/english/research/networks/hisp/>.

⁶<https://www.mn.uio.no/ifi/english/research/networks/hisp/hisp-history.html>.

DHIS1's approach was to decentralize and give power to the lower levels, so that they could utilize the captured information themselves. After DHIS1 started growing rapidly the two-user development team became a 'bottleneck' for further development when supporting several countries. The project did not use any software for sharing source code so it was hard to cooperate with other developers. For these reasons, including making DHIS cross-platform (moving away from Microsoft Access database), they decided to restructure the project and make it web based and they introduced version 2.

2.6.2 DHIS2

The DHIS2 was a project initiated from the University of Oslo and it was built on open source software and with intention to be cross-platform. Source code sharing was done through Launchpad⁷, which in 2006 was one of the best software for this purpose. Utilizing this software made it easier for developers across the globe to start contributing into the same Launchpad branch and committing code. DHIS2 has been introduced to several countries across the world and is utilized by 47 countries. It is accessible through the web browser and is thus cross-platform. A DHIS2 instance runs on one server that are able to communicate with a database which is always up to date, since users are entering data into the same database. Users have restrictions on which data they are allowed to see based on their work role. This means that they are not allowed to see patients in a health facility that they do not have any connection with. DHIS2 has also kept some of the flexible functionality from version 1, such as adding health facilities, data sets and disease programs. New functionality has also emerged such as the dashboard module where data is presented as graphs and charts. This has shifted the DHIS2 software from a database to a data warehouse (J. Braa and Sahay 2012). DHIS2 consist of two main modules for entering data: 'Aggregate' and 'Tracker'. The 'aggregate' module is targeting aggregated data and has functionality to present, interpret and analyze the data in charts, graphs and pivot tables. The 'Tracker' module targets individual patient records where tracked entities are entered in a specific programme.

DHIS2 Mobile Team

The DHIS2 Mobile Team is a global development collective that is focused on developing mobile applications for DHIS2. The team has in total 32 members⁸, consisting of active and non-active members, whom are coordinated from the University of Oslo. In this particular project, there has been collaboration with five members of the team; three software developers based in the Philippines and Vietnam, one application tester based in the Philippines and a project manager based in Norway.

⁷<http://www.launchpad.net>.

⁸<https://launchpad.net/~dhis-mobile-devs/+members>.

DHIS2 Mobile

DHIS2 has several mobile applications that utilize the software functionality through its application programming interface (API). The API is used for two way communication between a mobile client and the DHIS2 instance; retrieving and posting data. DHIS2 Mobile applications utilize different solution types such as a SMS solution, a browser based mobile client and application based client. Whereas the two first technologies are cross platform, the application based solution may be platform specific such as Android or using J2ME.

SMS Based solution

The SMS based solution is cross platform because of SMS support on every mobile phone. It is a robust solution with no need for Internet coverage and supports low end phones. A SMS based solution supports a variety of use cases⁹ such as:

- A simple web based interface for sending SMS to individual or groups of health workers or patients.
- Automatic SMS sent to patients, for example to remind them of an upcoming or missed visit, or as part of a general education program related to a health program.
- Reporting data by sending an SMS to the system.
- Sending messages from SMS to users of the system, for example for support or feedback purposes.
- Registering and enrolling a patient into a health program by sending an SMS.
- Entering individual health data for a patient visit using SMS.
- Checking the status of a patient's followup using SMS.

Browser based solution

A browser based solution is cross-platform because of the usage of web technologies through the web browser, thus working on both low end and high end mobile phones. However, this approach requires good Internet connection. An example of this application is navigating to a DHIS2 instance through a browser on a mobile phone. There is two versions available; one optimized for Android devices and one with a simple interface, optimized for small screens. This solution type is probably most applicable for users familiar with the web based data entry forms.

⁹<https://www.dhis2.org/mobile>.

Application based solution

This solution type may be platform specific or cross-platform, it depends on which technologies that are utilized. Two approaches can be used; a “native” approach and a “non-native” approach. The “native” approach utilizes technology which is specific to the platform, such as Java for the user interface on the Android platform, and Objective-C for Apple’s iOS platform. The “non-native” approach utilizes web technologies that are able to make use of the device’s hardware, such as sensors, GPS and camera. Such an approach may utilize Apache Cordova¹⁰ for development and this technology would create a cross-platform application.

There exist several application based solutions for DHIS2 on the Android platform, such as Data Capture that captures aggregate data including utilizing the ‘Tracker’ module for anonymous tracked entities (single event without registration). There is also a Messenger that let DHIS 2 users communicate on a Android device and an application that provides the ‘dashboard’ functionality for DHIS 2 on a Android device.

2.7 Android

Android is an operating system based on the Linux kernel and is targeting devices with touchscreen. It is developed by Google and the Open Handset Alliance and is released under licenses that makes it open source software. Android has over one billion active users each month and over one million applications ready to be downloaded through the Google Play Store. The newest version of Android operating system is 5.0 Lollipop and is used by above 3%, however most users do use the slightly older version 4.4 KitKat with over 40% of the user mass¹¹. Android is the preferred operating system for several large mobile phone companies, such as Samsung, HTC, LG and Sony. This makes the Android ecosystem the most used widely around the globe and it is thus attracting many software developers to create applications for this platform.

2.7.1 Android software development

The process of making an Android application is done through programming in Java and the user interface could also be programmed in Java or using XML mock up. To get started programming on the Android platform you need an Integrated Development Environment (IDE) such as Android Studio, Eclipse or NetBeans. An IDE needs to be configured with the Android software development kit (SDK) for getting access to the Android functionality. The developers of the operating system have provided a thorough and a clear documentation of the SDK. In the documentation,

¹⁰<https://cordova.apache.org/>.

¹¹<http://developer.android.com/about/dashboards/index.html>.

they provide examples for usage of functionality together with best practices.

This study includes the development of an Android application that is integrated with DHIS 2 software. The particular case is described detailed in chapter 5. Further, discussion about the solution type and a native approach was chosen will be provided in chapter 6.

Chapter 3

Theoretical background

In this chapter, I will present a theoretical background on which this study is based. First the design-reality gap model will be presented before it will be given a background of flexible standards. Finally, the concept of innofusion will be presented.

3.1 Design-reality gap model

The design-reality gap model compares seven dimensions of an information system and identifies the gap between them. The dimensions provided in the model are summarized by the ITPOSMO acronym and consist of:

- Information
- Technology
- Processes
- Objectives and values
- Staffing and skills
- Management systems and structures
- Other resources

Heeks (2006) states that the greater the gap is between the dimensions, the more likely the HIS is to be a failure. And equally, the smaller the gap is between the dimensions, the more likely the HIS is to be successful. Heeks et al. (2003) highlights three existing archetypes of project failure when the design-reality gaps are large. These archetypes are hard-soft gaps, private-public gaps and country context gaps. The archetypes are presented below.

Hard-soft gaps

This archetype occurs when the system design has not taken into account for 'soft' human issues, such as work culture, politics, skills and training. The 'hard' technical design should be built to support the 'soft' issues. If the

system is not designed to support the 'soft' issues the system is most likely not to be used in the intended way and therefore the system has a greater chance of failure (Heeks et al. 2003).

Private-public gaps

An information system designed for the private sector does rarely fit into the context of public sector, which is a common problem (Heeks et al. 2003). The private sector does not have the same work flow, culture or equipment as the public sector. This creates a large design-reality gap which will make the system likely to fail. An example of a private-public gap was when a regional health system in the United Kingdom was designed within and based on principles for the private sector for achieving objectives and apolitical decision making from skilled staff. These principles are not apparent in every public sector organization and later the project was canceled (Heeks 2006).

Country context gaps

This archetype is closely linked up with hard-soft gaps, but here we look past the technical human issues and see how the system fits into the current infrastructure of the country. It is important that the system supports the various infrastructural challenges that the country has, such as stable power supply, Internet connectivity and mobile penetration rates. Therefore it is rarely beneficial to adopt an information system that works in other countries, especially when adopted from a developed country into a context of a developing country (Heeks et al. 2003). Also when adopted from a developing country to another developing country, design-reality gaps may emerge and give the system less chance of success. An example of country context gaps is when an European based organization in cooperation with some western-educated locals were implementing a system for automation of customs data in a developing country. Although the system managed to automate some processes, it failed to achieve the majority of its objectives. It was perceived negatively by the the staff and thus achieved little usage (Heeks 2002a).

Heeks et al. (2003) describes a case in a ministry in a east African country. They were developing an information system that was supposed to support the decision making in the ministry, but the information system had large design-reality gaps. The system was designed to provide strategic formal information, but in reality the decisions were taken from gut feelings and informal information. The process dimension was designed to support structured decision making, but in reality, decisions were based on politics, personal opinions and human relationships. The system was designed to support a 'role culture', where rules and logic were valued, but in reality it was used to support a political environment that developed a 'power culture'. Organizational and proper structures were designed, but those structures did not exist in the ministry. Even though the system was cleverly designed, it did not fit into the ministry and they did not benefit from the structured information that was provided. These large design-

reality gaps caused the project to fail. This project is an example of a project failing when there are large hard-soft gaps.

It is also important to note that these issues and archetypes of design-reality gaps cannot be said to be limited to the context of developing countries. Conflicts between the hard and soft aspects of information system design can even be seen in developed countries such as Norway where health information infrastructures have failed (Hanseth et al. 2006).

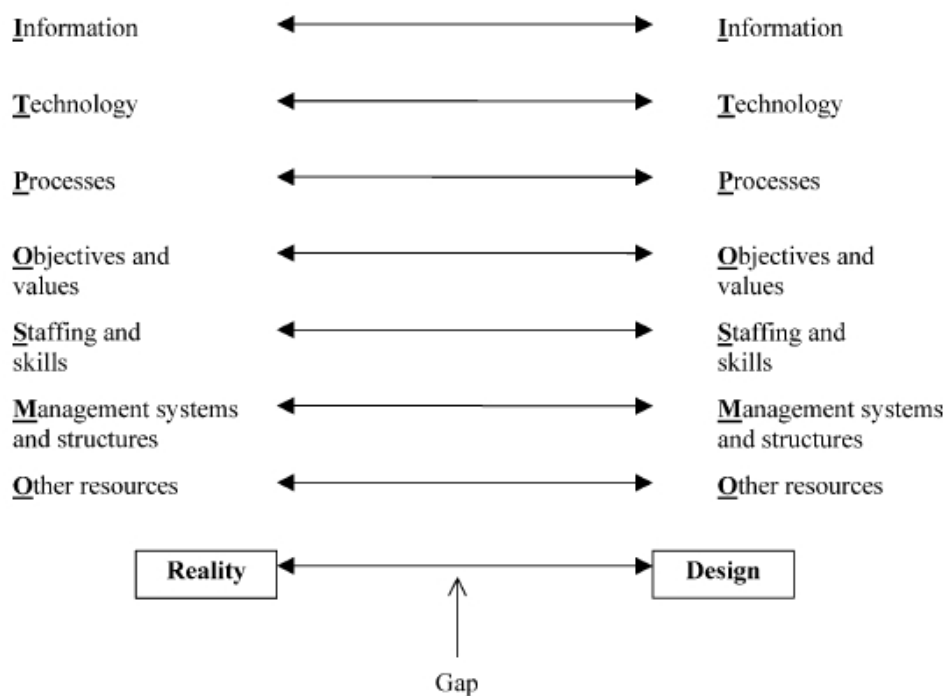


Figure 3.1: Design-reality gap model (Heeks 2002b, p. 105)

In a more recent paper by Heeks, he critiques his own work on the design-reality gap model. Heeks (2006, p. 132) argues that the dimensions of the design-reality gap model should be seen more as a checklist because the dimensions are “*a reminder of the essentially socio-technical nature of health information systems*”. Further Heeks (2006) argues that the archetypes of failure, as described above, can have too much of a static view which does not take into account an evolving organization and its ability to adopt. The ability to adopt can be forced or through innovation. Forced adoption can happen if funding gets decreased or stops, or if key staff decides to quit (Heeks 2002b). If this happens the organization is forced to adopt to new realities. The organization can also adopt through local improvisation to reduce identified design-reality gaps. Heeks (2006) proposes three aspects which can contribute to decrease the design-reality gaps. These aspects are methods, techniques and roles and competencies and are discussed below.

3.1.1 Methods

This aspect represents different approaches to deliver the system. As Heeks (2006) notes, HIS projects can be delivered via a “big bang” approach that switches from the current to a new system and users have to request changes to the system or find workarounds themselves. Another approach is the iterative approach that involves users in the specification and testing process. In an iterative approach a HIS project should be delivered in steps, such as modularity or incrementalism. Modularity supports one health care function before moving on to the next function and incrementalism provides support to one health care level of support before moving on to next level (Heeks 2006). Pilot and scale up is another possibility where one geographical region is supported before rolling out to new regions. To develop a useful system it is beneficial that the developers understand the context of the region. Users can contribute to this understanding and provide information about user-reality, but users can only do this if they understand the design of the system. Therefore a participative method is an important element to make the HIS implementation successful (Heeks 2006).

3.1.2 Techniques

This aspect is about how the developers get the tools to grasp the current realities. Observational techniques, such as first or third party-observing and documentation that describes the informal and socio-political reality are valuable for developers (Heeks 2006). On the other hand, rapid prototyping gives users the chance to understanding the design of the system and through this they are able to give proper feedback to close design and user-reality gaps (Heeks 2006).

3.1.3 Roles and competencies

This aspect is important because it is about how to integrate stakeholders that can work as a “hybrid”. Heeks (2006, p. 134) states that hybrids “*understand the world of the developer and the world of the user*”. This places the hybrids in a key role for improvisation between design and reality. Heeks (2006, p. 134) further states that the ultimate hybrid is “*someone who combines both developer and user within the same individual*”. Hybrids therefore act as intermediaries between designers and users of a system.

The theory on the design-reality gap model is relative thin and mostly covered by one researcher, Heeks. However, the design-reality gap model is not the only theory that seeks to resolve information system failure as it is a relative common problem in the world. Next, we will see how we can find the proper balance the user needs and organizational change through IT innovation. I will provide a background of two strategies; flexible standards

and the innofusion process, to see how these strategies can contribute to resolve the tensions that appear when an ICT system is scaling.

3.2 Balancing user need and IT innovation

Heeks (2006, p. 134) states that “*end-user development has been associated with successful HIS development ... however, this defines success in user terms*”. Giving the users an optimal solution may not give an optimal solution for the organization (Heeks 2006). The user needs can be represented as the installed base with some functionality that they feel is missing. IT innovation can be represented as organizational change which looks to resolve larger issues than only the user needs. There are several actors and factors at stake on both sides. At the user need side, obviously the user is represented, but it also affects the people that are supposed to benefit from the system. In the context of a HIS, the patients is represented here. On the other side, system designers are represented, but also national and international political actors may be represented here. It may be a problem here to find the proper balance between the two endpoints because political power may outweigh user needs in some contexts. At the other end of the scale, if the user get too much power, it may not be the perfect solution for the organization. The perfect balance can thus be seen as where users get the appropriate changes to the system which do not revolutionize the structure of the organization.

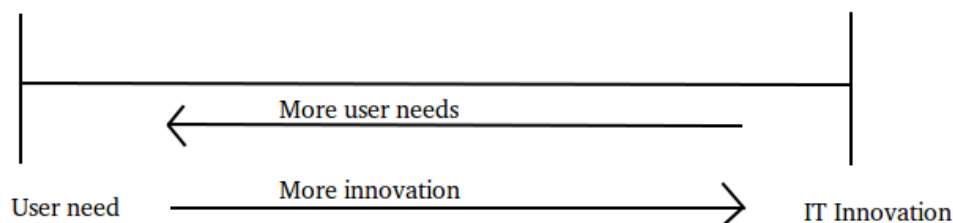


Figure 3.2: This figure represents the two “endpoints” user need and IT innovation.

In searching for literature for strategies for finding the proper balance between the two “endpoints” of the scale, two interesting topics have been found; The flexible standards strategy and the process of Innofusion. These topics will be discussed below to see if these can contribute to finding a solution that gives a successful adoption.

3.2.1 Flexible standards strategy

J. Braa, Hanseth et al. (2007) discuss how to create a strategy for flexible information system standards within the national HIS in developing countries. The strategy consist of creating a well designed attractor, that may emerge as a new standard. Crafting a standard is two sided; Even though the standard is well designed, it needs to have roots in reality to be useful. If the standard lacks roots in reality it may be hard to get users to utilize the

new standard. The standard therefore needs to be flexible. By being flexible it means having as little lock-in as possible so that the standard can fit into an ever-changing environment. It is also important to note that since there exist several standards within an organization, the standards also need to be flexible to each other, also across different levels of an organization.

Drawing from the above we can see that flexible standards and the design-reality gap model have quite a few similarities. They both have a clear link between design and user-reality, just like in the design-reality gap model. Flexible standards also recognize that the world is dynamic with a ever-changing environment and the same does the design-reality gap model. The different dimensions of the design-reality gap model can relate to the different flexible standards that the new standard are cooperating with.

Examples of an attractor can be a national data set, comprising of data elements from several different programs, that is shared and used by all health facilities in the country. An attractor can also be a list that contains all health facilities in a country. This can be seen as the backbone of a national HIS, thus making it an attractive attractor (J. Braa and Sahay 2012). However, in our case we are developing an attractor for collecting disease specific data on a device that is able to communicate direct with the national HIS.

In practice, as Heeks notes and the theory of flexible standards shows, the development and implementation of health information systems is dynamic. On one hand the reality is ever-changing and on the other hand, the design changes as more users and actors are enrolled. It is because of these changes we need a better “metaphor” to account for this. In reading literature, we can see a concept that relates to the process, innovation and diffusion of an IT artifact. In the section below I will introduce the concept of “Innofusion” as an additional perspective for addressing design-reality gaps.

3.2.2 The innofusion process

Fleck (1988) describes innofusion as “*processes of technological design, trial and exploration, in which user needs and requirements are discovered and incorporated in the course of the struggle to get the technology to work in useful ways, at the point of application*” (Fleck 1988, p. 3 in (Williams, Stewart and Slack 2005, p. 7)). Williams, Stewart and Slack (2005) notes that innofusion shows that innovation does not stop when technical artifacts emerge from production and into the diffusion stage where it is being implemented and used. Foster and Heeks (2013, p. 298) state that innofusion is used to “*recognise the continuity of innovation during the diffusion (e.g., scaling) of a technology*”. Further Foster and Heeks (2013) note two different perspectives for making ICT systems scale. The traditional, dualistic view and the systematic view, and an over-

view of the differences is listed below.

	<i>Traditional, dualistic view</i>	<i>Developed, systemic view</i>
Process	Innovation vs diffusion (scaling)	'Innofusion'
Stages	Pilot vs scale-up	Multiple phases
Roles	Lead firm innovator vs other actor diffusers	Distributed network (system) of innovators
Relations	One-way	Two-/multi-way
Nature of innovation	Technical vs social	Socio-technical
Organisational strategy	Planned (vs emergent)	Planned and emergent over time (shifts and drifts)
Strategic focus	Static: (MoP vs BoP; learning vs growth)	Dynamic, transitional

Figure 3.3: Differences between dualistic view and systemic view (Foster and Heeks 2013, p. 299)

Foster and Heeks (2013) presents four components of these perspectives; Process, Roles, Nature of innovation and organizational strategy. Whereas the dualistic view says that there are two different processes; innovation and diffusion which emerges through pilot and a scale-up, the systemic view recognize that these processes go through multiple phases.

The dualistic view seeks to cooperate in early innovation phase with local stakeholders. The Systemic view does, however, highlight the importance of a distributed network of innovators that include local actors that are involved in the whole process.

The systemic view also notes that it is important to see the whole socio-technical “organization” when innovating, thereby including technical, persons, relationships and organizational arrangements. On the other hand, the dualistic view has a more technical view of the innovation.

Organizational strategies are based both on planning and emergence. However, the differences between the two views is that the dualistic has a more static view on the target group. The systemic view is more dynamic and transitional which is based on shifts and drifts in the strategy. If a strategy is successful, it “*will lead to ‘drifts’ in strategy: emergent and reactive changes during the process of scaling*” (Foster and Heeks 2013, p. 299).

In this study I will use the concept of innofusion to see how the relationship between innovation and diffusion affects the development process. In chapter 6 I will discuss how the system is affected through user feedback and further discuss how theory fit into this project.

The next chapter will go through the chosen research method and the research approach.

Chapter 4

Research method

In this chapter I will present which research approach this study was based on, why the approach was chosen and I will also describe the approach. Further explanation and an overview of qualitative research, methodologies and data analysis will be given. Action Research and Canonical Action Research will also be presented. Finally, I will provide some notes of limitations of this study.

In order to answer the research questions, a practical study was conducted which included developing an Android application for the Ministry of Health and Child Care (MOHCC) in Zimbabwe. The application is targeting the issue of malaria in Matabeleland South province and supports the existing, and ongoing, pre-elimination program. The fieldwork included two trips to Zimbabwe in a four week period of July to August 2014 and a three week trip in February 2015. During the first trip an Android application was developed, working as a 'showcase' to show the power of DHIS2 with an Android extension. The second trip included a pre-pilot of the second generation of the application and meeting with stakeholders. The pre-pilot included a visit to several district hospitals and rural health clinics in Matabeleland South province to show them the application and understand the strengths and limitations of the installed base.

4.1 Qualitative research

There are two different research methods that can be used; qualitative and quantitative. Qualitative research allows the researcher to collect “*open ended emerging data with the primary intent of developing themes from the data*” (Creswell 2013, p. 18). This method focuses on interviews that are semi structured or unstructured to allow follow up questions which gives the interviewee an opportunity to elaborate on questions. Participant observation and analyzing documents are strategies also used by qualitative research for better understanding. Quantitative research uses surveys and experiments as strategies and “*collects data on predetermined instruments that yield statistical data.*” (Creswell 2013, p. 18).

One of the goals of this study was to understand the system used for malaria surveillance in Zimbabwe in order to improve it. Therefore this study uses qualitative research to answer the research questions and for finding out how to make the application work in context. Moreover, the aim was to understand which features enabled the users to do their tasks efficiently. Therefore interviews with users were important to help the understanding of which features were needed in context.

4.1.1 Research paradigm

There are several different paradigms that can be used in information systems research. The research paradigms help the researcher to understand the knowledge claims that can be made from a study. Klein and Myers (1999) note there are different research paradigms in qualitative research as discussed below

Interpretive

Just as its name, this research paradigm tries to interpret and make sense of the current reality. The "*aim of all interpretive research is to understand how members of a social group, through their participation in social processes, enact their particular realities and endow them with meaning, and to show how these meanings, beliefs and intentions of the members help to constitute their social action*" (Orlikowski and Baroudi 1991, p. 13). Interpretive research methods in the context of information systems is "*aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context*" (Walsham 1993, pp. 4-5 in (Klein and Myers 1999, p. 69).

Positivist

Information systems research can be classified as "*positivist if there is evidence of formal propositions, quantifiable measures of variables, hypothesis testing, and the drawing of inferences about a phenomenon from a representative sample to a stated population*" (Klein and Myers 1999, p. 69).

Positivist can thus be seen as building on objective knowledge and on recognized laws.

Critical

An important distinction between these research paradigms is that critical research has an "*evaluative dimension*" (Orlikowski and Baroudi 1991, p. 18). Whereas positivist and interpretive perspectives are explaining or predicting the reality, critical research evaluates and tries to make changes to the current reality. Critical researchers understand that changes can not

be done solely by the researcher and they do “*recognize that human ability to improve their conditions is constrained by various forms of social, cultural, and political domination as well as natural laws and resource limitations.*” (Klein and Myers 1999, p. 69).

The critical research paradigm is used because I am trying to understand how the current system is working. Hereby, we are identifying its strengths and weaknesses with intention to strengthen the current system by replacing it with a better system. To replace the system I recognize that political support from official actors is needed.

4.2 Action Research

I will now argue why Action Research is the best fitted research method for this project.

4.2.1 Deciding on Action research

To achieve the best results when researching, it is important to choose the best fitted research method for the case that is being studied.

Figure 4.1 was useful in choosing a research method from those used within the information systems research literature. I have in the red circles marked is the most relevant for the research conducted. The judgment is based on my own subjective opinions.

Table 2
Research method characteristics

		Research method					
		Hard case study	Soft case study	Action research	Action case	Field experiment	Quasi-field experiment
Research outcome	Change (intervention)	Unintended	Unintended	Intended, large-scale	Intended, small to medium scale	Intended, small-scale	Intended, small-scale
	Prediction (reduction)	Medium	Low	Low	Low	High	Medium
	Understanding (interpretation)	Medium	High	Low to medium	Medium	Low	Low to medium
Research characteristics	Duration	Any	Any	Long	Short to medium	Short	Medium
	Time orientation	Contemporary	Historic and contemporary	Building future	Contemporary and building future	Contemporary	Contemporary and building future
	Participation	Low	Low	High	Medium	High	Medium

Figure 4.1: Comparison of research methods (K. Braa and Vidgen 1999, p. 42)

From the figure 4.1 we can see which of the characteristics have been chosen. I will explain the choices below.

Change

It is definitely in our intention to facilitate change when implementing a mobile based HIS. Since the plan was for a region based pilot with a nationwide roll-out if pilot is successful. This qualifies as a large-scale inter-

vention.

Prediction

The prediction of this project is low to medium since there are some political factors at stake in this project, but this is beyond the reach of the researcher.

Understanding

Critical research is founded on the interpretive basis of understanding the phenomenon before intervening. Medium to low understanding is needed for this project.

Duration

This research project has a duration of 18 months which I think is classified as short to medium project time frame.

Time orientation

We are trying to modernize the HIS in Zimbabwe but also building a part of the future health care system.

Participation

Since the researcher was actively participating in the development process of the HIS. This will classify this as high participation.

On the basis of these characteristics and research outcome of the project, which is visualized through figure 4.1 above. It is close between Action Research and Action Case, however Action Research was the research method that was chosen in this project.

4.3 Action Research approach

This research was conducted within the Action Research (AR) framework which is very commonly used when researching information systems (R. Baskerville and Wood-Harper 1998). Furthermore AR is very appropriate for studying information systems because they place the researcher in a “helping role” within the studied organization (R. Baskerville and Wood-Harper 1998). Roode (2008) states that AR is an interventionist approach, that operates in the post-positivist tradition, to obtain scientific knowledge. Klein and Myers (1999) state that AR operates in the interpretive and critical tradition, both of which are post-positivist paradigms.

4.3.1 History of Action Research

AR has its origins from around the World War II which witnessed massive changes in the social and medical sciences. It is Kurt Lewin that is credited with inventing AR at University of Michigan, however, Soria (2014)

note that the history behind AR is unclear and that it had been used by others earlier. There was a group at Tavistock Clinic (later Institute) that worked independently using AR which had focus on psychological and social disorders. Lack of understanding of the complex illnesses did not lead to universal treatments, so the researchers started to do experiments on the patients. Since the researcher and the therapist were the same person, now the researcher was part of his own research (Roode 2008). In the 1970s, conflicts within the AR community appeared and it led to development of several different sub methods of AR. Checkland used AR with systems analysis, developed soft systems methodology and explicitly linked AR to philosophy and systems science (R. L. Baskerville 1999). Another historical important fragment of AR is the work by Argyris and Schön which introduced double-looped organizational learning (R. L. Baskerville 1999).

Action Research consist of two stages; diagnostic and therapeutic (R. Baskerville and Wood-Harper 1998). The former stage includes an analysis of the situation by the researcher and the subjects of the research. From this analysis, a hypothesis of the situation is developed. The latter stage introduces changes and an investigation of how the changes affect the situation is performed to inform the next cycles (R. Baskerville and Wood-Harper 1998).

	Process model			Structure		Typical involvement			Primary goals			Published IS examples
	Iterative	Reflective	Linear	Rigorous	Fluid	Collaborative	Facilitative	Experiment	Organizational development	System design	Scientific knowledge	
Canonical action research	•			•		•			×		×	Baskerville (1993)
Information systems prototyping	•			•		+	+				•	Kyng (1991)
Soft systems	•				•		•		×	×		Checkland & Scholes (1990)
Action science		•		•			•		×		×	Reponen (1992)
Participant observation		•		•				•			•	Jepsen <i>et al</i> (1989)
Action learning		•		•				•				Nair (1983)
Multiview			•	•		+	+	+			•	Avison & Wood-Harper (1990)
ETHICS			•	•			•		×	×		Mumford (1983a)
Clinical field work			•		•		•		×		×	Hammer & Champy (1993)
Process consultation			•	•				•	•			Coad & Yourdon (1991)

Key: • signifies a dominant characteristic, + (or) signifies characteristics that will dominate in different studies, × (and) signifies characteristics that may occur together in the same study.

Figure 4.2: Characteristics from the different methodologies in Action Research (R. Baskerville and Wood-Harper 1998, p. 96)

Although action research is famous for delivering results, it has been criticized for lacking rigor, especially in the analytical perspective (Davison, Martinsons and Kock 2004). These two stages do not provide enough detail to support this type of project and are not rigorous enough to ensure good research quality. To help choosing a relevant flavor of Action Research that fits the current project, I needed a flexible, rigorous and collaborative method that aimed at organizational change to support software development. I based my decision on the Action Research characteristics from R.

Baskerville and Wood-Harper (1998) as presented in figure 4.2.

Figure 4.2 shows that Canonical Action Research (CAR) suited this project and therefore I based my research on the principles of this method.

4.3.2 Canonical Action Research

CAR consist of five principles that aim to address organizational development and simultaneously contribute to the academic literature. Davison, Martinsons and Kock (2004, p. 69) note the five principles of Canonical Action Research as:

- The principle of the Researcher–Client Agreement (RCA)
- The principle of the Cyclical Process Model (CPM)
- The principle of theory
- The principle of change through action
- The principle of learning through reflection.

The RCA is an agreement between the researcher and the client and it includes how CAR works and which advantages and disadvantages it has (Davison, Martinsons and Kock 2004). Further it should contain mutual guarantees for behavior in the project and it should provide a solid basis on which the project builds on for all stakeholders. In this study I have obtained an agreement through a letter of invitation that is attached in appendix A .

CPM consist of five phases and describes a linear process of a proposed intervention. The five phases are: Diagnosis, action planning, action taking, reflection and evaluation (Davison, Martinsons and Kock 2004). This is an iterative process and a hypothesis can loop through the phases multiple times until the desired result is achieved. The principle of theory says that the research should be conducted within a theoretical framework and focus on one or more theories (Davison, Martinsons and Kock 2004). It is important for the researcher to have completed a thorough literature review to identify to which area of scientific knowledge the research is contributing to. In this study I am contributing to the literature of health information systems development in developing countries to see which strategies of innovation contribute to a successful adoption.

The principle of change through action notes the importance of change in the organizational context (Davison, Martinsons and Kock 2004). The researcher should gather substantial knowledge about the studied organization and know the changes that should be done, justify what should be done and why it is the best option. After the change has been implemented (or even if it has failed), analysis should be documented for future learning (Davison, Martinsons and Kock 2004). In this study there have been several changes through action. First of all, the platform of the system was

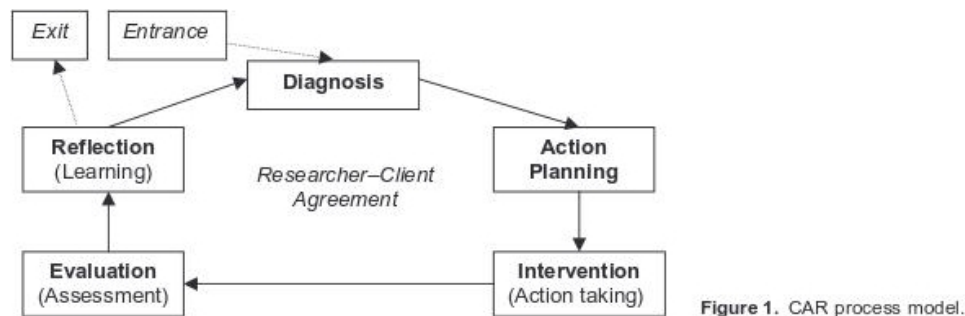


Figure 4.3: This figure shows the CAR process model (Davison, Martinsons and Kock 2004, p. 72)

changed from Windows 6.5 to Android. The reason for the platform change is to utilize newer technologies on a broader platform.

The principle of learning through reflection highlights the importance of reflecting on the actions and results (Davison, Martinsons and Kock 2004). This helps the researcher to contribute to the existing literature within the studied area and the results contribute to organizational development (Davison, Martinsons and Kock 2004). In this study reflection on previous development phases has been important to optimize the next solution, such as when moving from the initial Android prototype to the DHIS2 Tracker and from DHIS2 Tracker to Tracker Capture and Event Capture.

4.3.3 Research approach

This thesis will be based on this understanding of Action Research with the principles from CAR above. However, I will use a less strict CPM. All processes were not linear and it was beneficial to be flexible and to jump between the phases in the model. In this project, the principles of CAR has been used in the cycles as presented below

We have currently an one-year contract with the MOHCC which clearly states the goals of the project and how the project, in the best way, shall be completed. The high level decisions of the project have been prepared by the MOHCC, such as an application that tracks malaria patient. The technical decisions, such as choosing Android as a platform was made by the researcher. The MOHCC also provided a letter of invitation for the researcher, thus making it easier to get in to the country and to do the necessary field work including interviewing key staff. This can be seen as our RCA.

All processes, hypothesis' and actions went through the CPM and the mentioned phases as described above. However, as noted, it was used a less strict model, making it non-linear and thus allowing jumping between

all phases. The reason why it is done this way is clear; Software development is often characterized by testing and failing and since requirements can be changed at any time we need to be flexible.

Theory, such as the design-reality gap model has been kept in mind when designing the applications to make it fit the current reality. The purpose of the first field trip to Zimbabwe was to get key stakeholders interested in the project and also involve local software developer organizations to maintain the system in the future.

The reflection part of the project is at the end of this document and reflects on how well the research questions has been achieved and if something could be done better.

Even if I did not use CAR in the rigorous way it is presented by Davison, Martinsons and Kock (2004), it has been very beneficial to the theoretical and the practical work. Below I will present my Action Research cycles.

4.3.4 Action Research Cycles

In this section I will present the AR cycles that the empirical work of this thesis has went through. There were developed in total four Android applications in this project. Firstly, an Android application that was a proof-of-concept, showing that it is possible to make such a malaria tracker application extension of DHIS 2. Secondly, an Android application was developed with the intention of being piloted. Finally, two new Android applications were developed for dividing up different work processes. The reason for development of four different applications will be explained in case description (Chapter 5).

First cycle

In this cycle the paper-based forms from the NMCP was customized into the DHIS2 software. The customization included removing duplications of data elements as well as introducing skip logic in the forms. This cycle was conducted in Oslo in the first months of this project.

Diagnose: The paper-based forms provided by NMCP has too many duplications. Further, some data is not necessary to collected based on data from previous data elements.

Planning: Identify the duplicate data elements and locate questions that are bound to other questions for introducing skip logic.

Action taking: Actions were taken to remove the duplicate data elements and data elements were moved into the programme enrollment in DHIS2. Action were also taken to introduce skip logic into the forms using

JQuery.

Evaluation: Evaluation of the forms was done by me and my supervisor.

Specify learning: We found out that it was possible to reduce number of data elements to be collected in the forms.

Second cycle

This cycle included the development of the Android prototype application, which initially utilized the customized forms from the first cycle. However, when the new forms developed by MOHCC were discovered, the work from the first cycle was discarded. The prototype aimed to be a 'showcase' application that displayed the power of DHIS2's functionality extended to an Android device. This cycle was partially conducted in Oslo, but mostly in Harare, Zimbabwe.

Diagnose: Data collected from the pre-existing system needs to go straight into the national HIS, not in a vertical system.

Planning: Develop an application that communicates with the national HIS in Zimbabwe.

Action taking: An Android application was developed as a data collection tool to enable communication with the national DHIS2 instance.

Evaluation: At the end of the cycle the application were evaluated by me and my supervisor.

Specify learning: During the evaluation we recognized that it was possible to make an Android application communicating with the national DHIS2 instance. Further, I learned that the Android platform is a good choice in the context of Zimbabwe.

Third cycle

The third cycle included merging the use cases from the second cycle into a new Android application: the Zimbabwe DHIS2 Tracker. This application was built on experiences gained from the second cycle. The Zimbabwe DHIS2 Tracker aimed at being piloted in Matabeleland South Province. This cycle was conducted in Oslo, working with a part time programmer and the DHIS2 Mobile Team to some extent.

Diagnose: There is a need for a data collection tool that enables offline functionality

Planning: Migrate the use cases from the previous cycle. Modify and further develop the provided DHIS2 Tracker and utilize the DHIS2 Android SDK.

Action taking: When migrating the use-cases, the Zimbabwe DHIS2 Tracker emerged. All major requirements such as offline functionality, utilizing NMCP's forms and capturing of patient specific malaria data were achieved.

Evaluation: A pre-pilot of the system were arranged to evaluate the Zimbabwe DHIS2 Tracker. All stakeholders such as the end-users, the developers of the application, other local Zimbabwean actors evaluated it.

Specify learning: Offline functionality was added through utilizing a local database on the Android device.

Fourth cycle

Because of the emerging interest from new actors, this cycle included developing a new standardized Android application, built around the use case from the third cycle. The development responsibility had now been overtaken by the DHIS2 team. Even without being directly involved in the programming of the new application, I had a key role forwarding user needs, and also enrolling local developers in Zimbabwe.

Diagnose: Disease surveillance on an Android device is something several other actors want. We need to find a way to standardize the Zimbabwe DHIS2 Tracker, however with maintaining Zimbabwe's key role.

Planning: Need to get local developers on the project. Also need to share my experience and the data collected from the pre-pilot with developers of the applications.

Action taking: Developers at HITRAC were enrolled as programmers on the disease surveillance application. Further, information has been given to the developers to ensure that the applications fulfill user needs.

Evaluation: Cycle still ongoing.

Specify learning: Cycle still ongoing.

4.4 Data collection and analysis

Data was collected through several methods to cover the whole aspect of the research. Qualitative research with techniques such as participant observation, field notes, interviews and analysis of documents were used. The gathered data was analyzed for contributing to resolve the research questions.

4.4.1 Interviews and discussions

The interviews were semi-structured because that opened up for some flexibility where the interviewee can elaborate on their area of expertise, and this form of interview is within the scope of qualitative research. The interview were recorded only if the interviewee allowed it, later to be transcribed. Nevertheless, notes were taken at every meeting. The interview questions were reviewed after each interview to ensure that they contributed to good data quality.

There has been conducted several interviews with the project's stakeholders. When interviewing for the pre-pilot, several persons that were both primary users and secondary users of the current system were interviewed.

The answers from the questions is discussed in discussion and findings (Chapter 6).

4.4.2 Emails

Email discussions were important to gather data, especially for communicating with stakeholders when not on the ground in Zimbabwe. Emails were also a important tool for communicating with the DHIS 2- core and mobile team which is located around the world, the developers at HITRAC, workers at CHAI and the users (that were working as testers) of the DHIS2 Tracker application in the Matabeleland South Province.

4.4.3 Participant observation and field notes

It is not easy to remember all the happenings of a day, therefore taking field notes was very important. It was pointed out by my supervisor that taking field notes is very valuable when writing the thesis. Field notes were taken in different settings, such as in field trips, meetings and sporadic ideas were written down on a notepad. Along with the field notes, pictures were taken to capture moments with my mobile phone. After each day, the physical field notes were transcribed into a structured document with a more reflective view on my laptop. Participant observation was used when trying to understand the current system and I participated in several meetings where I got the opportunity to try a PDA. Meetings with remote stakeholders were conducted using Skype. Skype meetings were held with the DHIS2 Mobile Team based in Vietnam and the Philippines.

4.4.4 Data analysis

All the qualitative data was analyzed and coding was used. Coding and marking key words in the structured field notes was valuable to answer the research questions together with the findings and data from each AR cycle.

Document analysis

Document analysis was conducted for generating more information about the context of Zimbabwe and other documents that were important for implementation of the new application. Key documents that were analyzed were:

- The Zimbabwe e-Health strategy
- DHIS 2 Documentation for developers
- NMCP documents for malaria pre-elimination

AR does not have any explicitly data analysis phase so next I will go through the limitations of AR and the research limitations in general.

4.5 Research limitations

Because I did not take a course in AR, I base my understanding of the research methodology on what I have read from different sources, such as power point presentations, papers and discussions. The understanding was weak on the first field trip and including the two first AR cycles, but it was better during the second field trip, including the third and fourth AR cycle.

Another limitation was the issue of language. Even though the official language in Zimbabwe is English, which was spoken in all of the meetings, the informal conversations are often in one of the native languages. Thus it was hard to pick up some of the ongoing discussions between meetings.

Furthermore, R. L. Baskerville and Wood-Harper (1996) notes four problems of concern which are not especially bound to Action Research itself, but research methods in the field of social science.

Impartiality of the researcher In AR studies where the researcher is directly involved in the process of change, the results presented may be impartial, because the researcher want to promote the work conducted. In our study we are looking at how we can get a new HIS is successfully adopted in the whole organization. Heeks (2006) argue that it is a problem to know when to assess an information system. Furthermore, if it is a success, it is important to note which actor has succeeded and what the definition of success is (Heeks 2006).

Lack of rigor AR is often criticized on its lack of rigor because the researcher can get too involved (R. L. Baskerville and Wood-Harper 1996). In this study this may be true, as stated in sub section 4.3.1, CAR has not been used in a rigorous way to be friendly for software development. It is lack of rigor is because the researcher has several roles; researching, representing the organization and representing the users.

Consulting work, but concealed as research This limitation is valid for most research, but this study can not be seen as consulting because the researcher was not being paid by any organization and was doing volunteer work.

AR is context-bound As R. L. Baskerville and Wood-Harper (1996, p. 241) notes, since AR is context-bound to the environment, “*action research produces narrow learning in its context because each situation is unique and cannot be repeated*”. This study is not seeking to standardize the way of resolving the problem of information systems in developing countries

In this chapter we have seen how the research approach has been used and looked at the theory behind it. In the next chapter the research case will be presented with the empirical work of this study.

Chapter 5

Research case

In this chapter I will provide a background of the socio-economical problems of Zimbabwe where this study was conducted. The study included a four week long field trip to Zimbabwe in July and August 2014 and a three week field trip in February 2015 when the country was in a political and economical crisis. This will give the reader an insight of the factors which have contributed to this current situation. Further I will present how the health care system in Zimbabwe is, and finally I give a thorough description of my empirical work within the Zimbabwe context.

5.1 Zimbabwe

Zimbabwe is a developing country in Africa and is located in the south-east on the continent. The population is 14.150 million¹. The biggest city is the capital, Harare and it has over 1.5 million inhabitants. Zimbabwe is a landlocked country which borders with Mozambique in the east, Zambia in the north, South Africa in the south and Botswana and Namibia in west. The country is divided into eight provinces, with cities like Harare and Bulawayo also having provincial status. The provinces are subdivided into 62 districts and further into 1200 wards.

The country was in the 1980 first recognized by the UN as independent after being under British rule. At independence, the Zimbabwean government had a primary focus on education and free health care for the poor (Sanders et al. 1990). In the following years, there were several political changes that led to the current sanctions that the country is now suffering from. The sanctions have had a major impact to the welfare of the every-day-Zimbabwean. They have contributed to the suspension of necessary maintenance of public infrastructure and funding to public institutions. Moreover, it was especially the public infrastructure in rural areas that suffered most (Sanders et al. 1990). There is still no stable electric power or definite clean water for everyone. The infrastructure is very asymmetric, where the infrastructure is best developed in the large cities, how-

¹<http://www.who.int/countries/zwe/en/>.

ever the majority of Zimbabweans live in the rural areas. The focus on education since independence has given results in adult literacy rate, which is the highest in Africa at 91 per cent².

As a result of the sanctions, hyper inflation occurred that traumatized the population. In 2009, the government had to migrate to a multi currency system to restrain the inflation. This change had a positive effect to the economy and the following years Zimbabwe has seen buoyant economic growth. However in the economic crisis, the government had to suspended the good cooperation between the education- and health care system. This led the country failing to educate qualified health informatics workers.

5.2 Mobile phone usage in Zimbabwe

Mobile phones are becoming more widespread in Zimbabwe, just like in other developing countries. Africa Mobile Networks³ states that the 80% of the population and 50% of the land has mobile network coverage from at least one of the three network providers (Econet, Net-One and Telecel).

Figure 5.1 below shows that the most used operating system today in Zimbabwe is Android with a user base of over 50 per cent and has seen rapid growth the recent years. Series 40 (S40), which is the software platform of Nokia devices, has a share of about 24 per cent, which has declined in recent years.

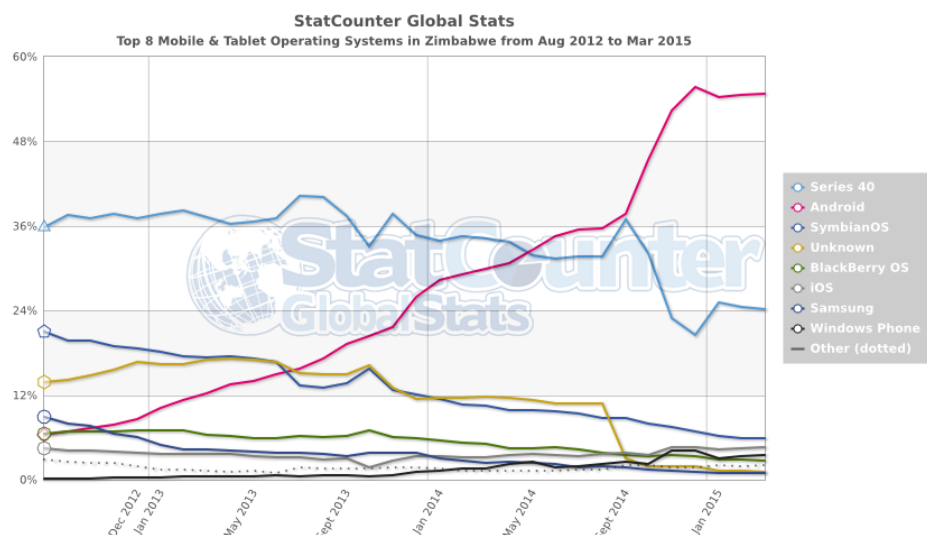


Figure 5.1: Graph of distributed mobile phone and tablet operating systems in Zimbabwe. Statcounter

²<http://www.sabc.co.za/news/a/5c11890044581c8fbd02fd744a7933f3/Zimbabwe-leads-literacy->

³<http://www.africamobilenetworks.com/our-coverage/zimbabwe>.

This survey has some flaws where it shows both Android and Samsung and an 'unknown' statistic that has a impact on the graph. Samsung is a mobile phone distributor and not a operating system, it gives this survey some doubts. Samsung provides several different operating systems to their mobile phones such as Tizen, Android and Bada. However, general trends can still be obtained from the graph.

5.3 Zimbabwean health care sector

The Zimbabwean health care system is a hierarchical structure with four layers: primary, secondary, tertiary and quaternary. It consist of facility level, district level, provincial level and national level. MOHCC⁴ notes that primary health care (PHC) is the heart of the Zimbabwean health care system and its main components are:

- Maternal and child health services
- Health education
- Immunization
- Nutrition and food production
- Communicable diseases
- Water and sanitation
- Essential drugs
- Preventive and curative services

The health care system consist of both public and private health care, where 65 per cent of health facilities are publicly owned and 35 per cent are privately owned⁵. Before the crisis, the Zimbabwean health care system was known as one of the best in the region and had well educated, skilled and experienced personnel⁶. In recent years Zimbabwe has experienced a bigger demand of their public health services and the economic crisis has led to shortage of human resources. The reasons for this shortage are reported to be out migration, low salaries, difficult working conditions and increased risks of being infected by diseases⁷. During the crisis the Zimbabwean health care system has not been sustainable and could not support it self, so they requested funding from the international donor community. This has resulted in that they now rely on donor-supported vertical programs for several major health issues, including delivery of necessary drugs and prevention products . This is mainly a short term fix, but for Zimbabwe to be self-sufficient and have a sustainable health care system, they need to

⁴http://www.who.int/goe/policies/countries/zwe_ehealth.pdf.

⁵<http://apps.who.int/gho/data/node.country.country-ZWE>.

⁶<http://www.usaid.gov/zimbabwe/global-health>.

⁷http://www.healthsystems2020.org/files/2812_file_Zimbabwe_Health_System_Assessment2010.pdf.

establish a new health management information system. The international donors have also funded this project, and this has led to the implementation of the DHIS 2 software. The official launch of DHIS 2 was in the summer of 2014 and was reported to be a success.

Zimbabwe is facing the challenges of today's major diseases, such as HIV/AIDS, tuberculosis (TB), cholera and malaria and is receiving support from the donor community to get the proper systems in place. Different parts of the country are facing different challenges, some diseases, such as malaria are mostly widespread in Manicaland, which is located in eastern Zimbabwe. In Manicaland they have tens of thousands of cases each year because of a optimal climate. However, malaria is a common problem also in the rest of Zimbabwe but the cases of confirmed malaria are decreasing since 2005, yet confirmed cases have grown since 2009⁸.

5.4 The malaria pre-elimination project

The MOHCC and National Malaria Control Programme (NMCP) started the project of malaria pre-elimination in the province Matabeleland South. The reason why they chose this province was because of the manageable number of confirmed cases every year. Matabeleland South is a huge province, but malaria is most widespread in the southern parts of the province along the borders to Botswana, South Africa and Mozambique. Some people that live in these areas are tribal people that are not permanently settled and may live on both sides of country borders. For this reason, cross-boarder collaboration with neighboring countries is crucial to stop disease transmission. NMCP's approach to stop transmission for eliminating malaria is to follow up every infected person and also check other people in the same household. The Environmental Health Technician (EHT) is responsible for this job within the assigned area (ward and districts). The malaria surveillance system is tailored for the EHT's tasks when going in the field where lack of Internet connectivity is a common problem. The EHT's tasks for the malaria program are:

- Enroll the patient into the program when they arrive at the health facility and test positive for the disease.
- Investigate and follow up the patient in their home. GPS coordinates shall be captured.
- At patients home, a malaria test for all residents is conducted.
- Capture GPS coordinates on the suspected breeding site
- Log fuel usage for the trip

The EHTs are equipped with a PDA for entering data for malaria patients. The information that is entered into the PDAs is transmitted into

⁸http://www.who.int/malaria/publications/country-profiles/profile_zwe_en.pdf?ua=1.

a vertical system. The data is manually merged from the routine paper-based system into DHIS2 at district level. This creates an extra burden of work for health care providers. Decision makers and managers are expected to utilize this information for detecting outbreaks, distributing drugs and doing preventive work. In Zimbabwe, they have recently started a competition between health facilities where they compete in delivering best quality data. Money is the incentive for the best performing health facilities, but as seen in Sierra Leone⁹ they also compete because of pride and they do not want to lose to their neighboring health facilities and districts.

5.4.1 Organization of the project

A chart of the projects organization is shown in figure 5.2 below.

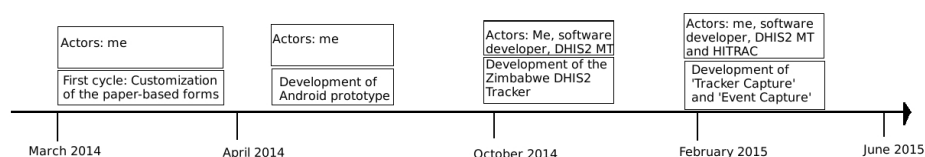


Figure 5.2: Showing organization of the project

This figure shows all the four cycles this project has undergone. In the first cycle I did the customization of the forms in the DHIS2 software. This cycle lasted one month from March to April 2014. In the second cycle, I developed the Android prototype application. This cycle lasted from mid April to September. The third cycle lasted from mid October to mid February 2015, and included the development of the Zimbabwe DHIS2 Tracker. This application was developed in collaboration with me, a software developer and the DHIS2 Mobile Team. The fourth cycle was the development of the standardized version from the result of the third cycle. 'Tracker Capture' and 'Event Capture' was started in February 2015 and the development should last until June 2015. These applications was developed by a software developer at University of Oslo, HITRAC and the DHIS2 Mobile Team to some extent. My contribution to this cycle is with a researcher perspective with having a role as getting requirements and engaging programmers. But I was also engaged in proposing ideas and features from my experience in Zimbabwe.

Before going specifically into the work cycles, the installed base for malaria surveillance will be presented

⁹<http://www.uio.no/studier/emner/matnat/ifi/INF5761/v14/timeplan/case-study-sierra-leone-league-table>

5.4.2 Installed base

The National Malaria Control Programme is using two systems for malaria surveillance, where one is a system that runs on PDA's on the Windows 6.5 platform. They also have a paper based system which is working as a backup system, if the PDA's is not functioning properly. The PDA's include a pre-configured application that has hard coded meta data which is specific to the assigned health facility. One PDA is distributed to each health facility and it comes with a quarterly pre-paid USD \$1 airtime so that the environmental health technicians (EHTs) are able to submit data over mobile Internet.

The PDA are robust devices which contain GPS functionality that enables capturing accurate GPS coordinates. The PDA also comes with other pre-installed applications such as Internet Explorer, Microsoft office and the malaria surveillance application. The malaria surveillance application contains seven forms that all need to be filled out for each person enrolled in the program.

The seven forms are presented below with a description:

T-12:

The first form that is filled out for a person. Contains basic personal information, and information regarding treatment and if the patient is referred.

Malaria register:

This form is filled out at the health facility when the patient is diagnosed with malaria. It is collected information regarding the malaria tests, if there has been an indoor residual spraying at patients household or if it has been used a bed net.

Case investigation:

This form is used three days after the malaria register and are collected at the patient's household. GPS coordinates of the home are collected and also an investigation concerning protection against the mosquitoes is done.

Contact screening:

This form collects information about other people living in the same household, with intention to stop transmission. It is collected basic information about the person and a malaria test.

Contact follow up:

This form is used if the person in the same household has tested positive on the malaria test. Information about the treatment given is collected. When a contact has tested positive, the contact now needs to be registered in the program and do all the forms above.

Entomological investigation:

This form collects information about where the patient has been infected by the mosquitoes. GPS coordinates from the breeding site are collected and

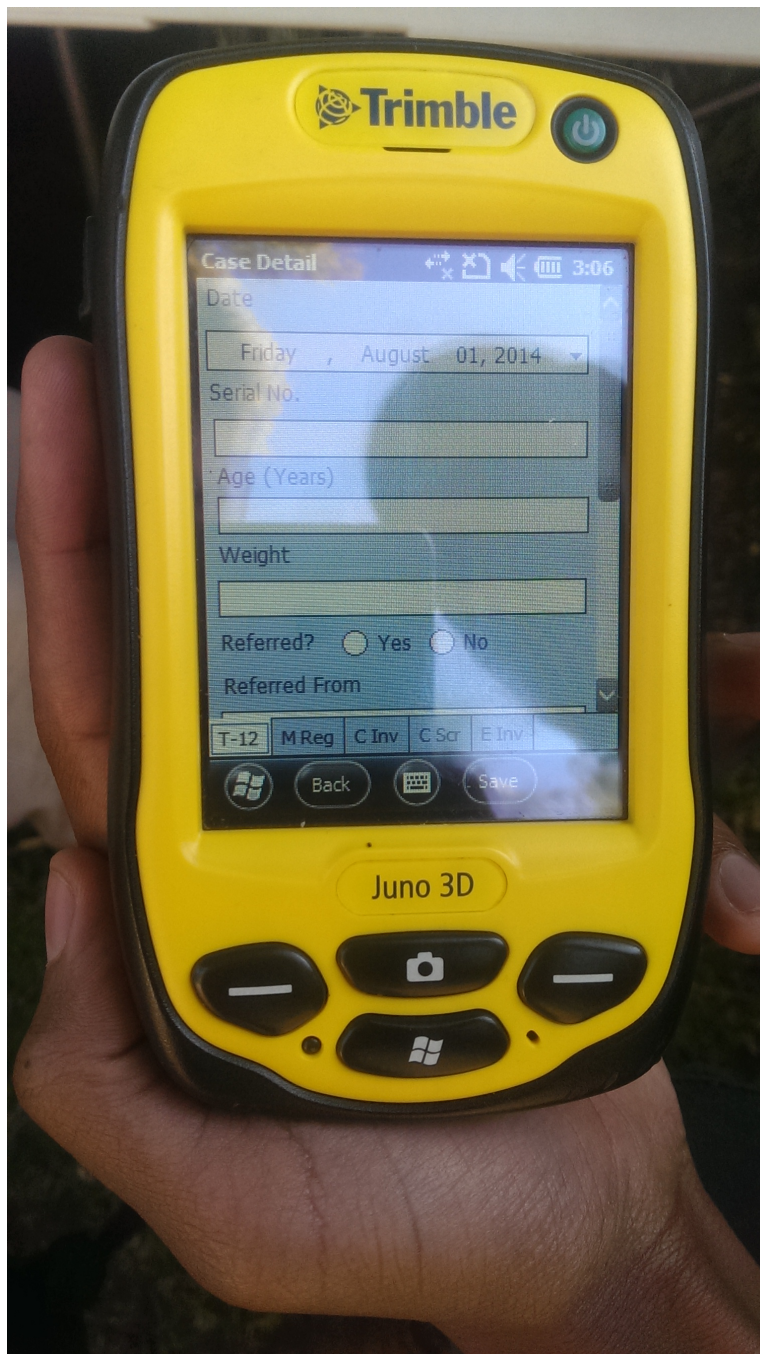


Figure 5.3: PDA that is currently being used for data capture in the malaria program. Here showing the T-12 form.

what type of landscape (River, pond, well etc) it is.

Fuel log form:

This form collects information about how much fuel being used investigating the patient and how much mileage covered.

These forms have been developed for several months by the MOHCC to optimize them for touchscreen devices. In this process they have reduced the number of data elements that are to be collected. Further, most of the questions are formulated into yes/no-answers or into option based answers. The purpose of reformulating the questions is to limit the risk of EHT's of entering data of poor quality. Examples of poor data quality can be entering 'zero' when it is expected the number "0" for calculation purposes. Questions with option based answers also limit the risk of entering data of poor quality.

5.4.3 Customization of the original forms

Being unaware of the work ongoing in the MOHCC with optimizing the forms for touchscreen devices, I started to do this work inside the DHIS2 software. The intention was to keep the original design but reducing the number of data elements. My work had its basis on the paper-based forms. It was noticed early that the questions were too long, complex and required a lot of text answers, and this was not very touchscreen friendly. The forms had duplication of data elements that were eventually reduced. Further skip logic was introduced into the forms using HTML5 and JQuery. JQuery is a library of JavaScript, it was used to hide data elements if they were not relevant, based on answers from previous questions. An example of this is if a patient already is registered as a male, it is not relevant to ask if the patient is pregnant. Neither is it relevant to ask about date of birth and then ask for the patients age. This is typically duplication that the system is capable to calculate it self using simple logic. In the case investigation it had data elements asking if today was day 3, 7 or 14 after registering. To reduce this I used DHIS2's native functionality with 'repeatable stages' so that one investigation form is filled for each visit. Finally, there was some restructuring of data since in DHIS2, patient details are collected at enrollment of the program, thus it is moved away from the forms.

Ironically, my work to reduce duplication in the forms and reformulating the questions was duplication of work since the MOHCC was redeveloping the forms themselves and had dedicated several months on this task. At this time there was no clear communication between me and any other stakeholders with the NMCP, so there were no way of knowing about it.

5.4.4 Android prototype

This section covers the purpose of the application and a thorough description of the development phase. The development phase started as soon as I felt that the customization of the forms was good enough.

Purpose of the application

The purpose of developing this application was to show that it is possible to utilize the 'Tracker' functionality in DHIS2 and put it into an Android

device. It was going to be a 'showcase' to the stakeholders in Zimbabwe to show them the power of DHIS2 and the flexibility of its application programming interface (API). I considered how common Android devices were in Zimbabwe before choosing this platform. Also, Android as an open platform is much more accessible, so it was known that it was already a better platform than Windows 6.5. The core architecture of the application and choice of technologies was chosen on the basis of workload versus functionality gained.

Development phase

After the DHIS2 forms were satisfactory, I started the work on developing an Android application that was going to collect information and post it to the DHIS2 server database. The application was communicating with the DHIS2 through its API. To enable this communication you have to speak the same language both to express what you want and to interpret the answer. As I see it, there are two existing technical standards for communication with servers: XML and JSON. XML requires some overhead and uses more resources to parse the values¹⁰. To communicate with the server JSON was used, which is the most common language for this purpose and has the advantages of being very light weight and easy to use. However, the application was based on instant JSON replies from the server and thus you needed to be online to retrieve the information. The application was based on the user restrictions, just like in DHIS2 web application, and the logged in user could only see the information that was available for him. This means that the user can only post information and see patients that are assigned to the same health facility (organization unit). To exploit the work from previous cycle, the program stages (forms) were generated through HTML code from the API and displayed on the Android device through a web view. This approach gave an identical copy of the forms just as in the DHIS web application, also this approach was very flexible since you just needed to update the design, data elements or the structure of the forms on the server and thus you updated every device running the application. Since the application was utilizing the API for connections, it made the application flexible, and at that time it was supporting different instances of DHIS2 above the targeted 2.14 version.

However, this application had not targeted all major requirements. At the time there was no offline functionality developed yet, which was one of the main requirements for this project. For offline functionality you needed a database structure in the back which was not developed. Further, the technical choices contributed to a difficult work environment. It was found challenging to combine Android code with the web technologies, HTML5 and JQuery. To make these technologies work together I had to develop an Android to JavaScript interface so that I was able to execute JQuery code within the application. Since it was chosen to display the forms using

¹⁰<http://www.json.org/xml.html>.

HTML5, I had to collect the data entered in the text boxes with JQuery and then parse it into a *'BasicNameValuePair'*, which is a list in Java that can hold two values. Here I added the data element ID to the first value and the text, that were entered by the user, into the second value. For completing a program stage for a malaria patient, the application sent the chosen patient ID, organization unit ID and program stage ID together with the data element list to the server. Although this approach was successful, these basic application design decisions utilizing web technologies were giving me trouble. At the beginning it seemed like that this approach would be less work, but it was actually more work and it gave me more trouble than I could anticipate.

This application was mostly developed in the first field trip to Zimbabwe. I took the basic design, architectural decisions and briefly started developing it before leaving. The rest of the development phase was conducted in HIRAC's offices in Harare. There I was working within a development team consisting about twenty people and had access to get help from several certified Java developers. The purpose of the internship was two-sided; trying to generate interest from a local company to get more developers involved in the project, but also to be visible and show that we were serious on this project to get in touch with stakeholders. Real business is still done face to face and not over emails, so to be present in Zimbabwe was crucial to meet stakeholders such as ZimHISP and Clinton Health Access Initiative (CHAI). Both ZimHISP and CHAI are doing project with the MOHCC today and were important contacts for further collaboration. CHAI was responsible for the pre-existing malaria surveillance system, however they did not have any programmers and had employed software developers from Ethiopia to do the programming for them. Until this time I was using my own customized forms, but after meeting with CHAI, they shared the new touchscreen optimized forms that they were using in their system. The new set of forms were to some extent similar to my customization, but they had added some new forms and reduced several more data elements that they did not find important to collect. Skip logic was added to the forms and they also included a set of indicators that they wanted to calculate, such as how many people were treated with Quinine and percentages of confirmed cases for men and women.

Later on in the field visit I got included in a email discussion within the DHIS community about data security on Android devices. This led to someone introducing me to the head of DHIS2 Mobile Team which was located at University of Oslo. They were doing some interesting work making an Android software development kit (SDK) for DHIS2. The SDK consists of all the trivial methods, such as connection to the server, parsing and serializing of the data that is going to be interpreted or submitted. The SDK did also provide a example application ('DHIS2 Tracker') that were utilizing the SDK. This application had a database structure that saved some data from the server into a database. After being introduced to this project I recognized that the DHIS2 Tracker had solved some requirements of the

Event date

2015-2-9

59

10

MALARIA CASE INVESTIGATION FORM

NATIONAL MALARIA CONTROL PROGRAMME

Were you able to complete the case investigation?

What was the reason for not investigating?

Are LLINs hanging in the house?

Did patient sleep under LLIN last night?

Was IRS conducted last season?

Date of last spray

Did patient sleep in

Figure 5.4: Completing case investigation form for the patient Peter Jackson in Android prototype application

Zimbabwe project, which would save me many hours developing. Therefore I looked into how to get the prototype to utilize the Android DHIS2 SDK. The structure of the Android prototype and DHIS2 Tracker was quite different, and for me to benefit from DHIS2 Tracker's code it would need major tweaks of the code. At this time I decided to migrate to the SDK, but I

wanted to finish my prototype first so that maybe it could generate interest from the stakeholders.

After finalizing the prototype, it was presented first to HITRAC, but no one really showed interest in the project at that time. However, they did appoint two people to follow up on the project if it should be interesting in the future. The application was also presented to CHAI which showed some interest and were positive for further collaboration, even though this was without technical support. CHAI would be supporting with talking to stakeholders and share information from them. They did see the potential of the DHIS2 software and since it was the new main HIS in Zimbabwe they saw potential for this project too.

In September 2014, the Android prototype was presented at an annual conference organized by the Provincial Medical Director for Matabeleland South Province.

5.4.5 Merging the Prototype and the DHIS2 Tracker

This section will cover the purpose of the new application and the development cycle of the Zimbabwe DHIS2 Tracker

Purpose of the application

With the experience gained from the Android prototype, we were building an Android application that was meant to be piloted in Matabeleland South Province. The Zimbabwe DHIS2 Tracker is based on the DHIS2 Android SDK which includes all the trivial methods for communication with the server.

Development phase

After coming back to Oslo I started the work with migrating to the SDK, but I quickly realized that it was difficult to migrate the two projects because of the completely different code structure. Before making this decision, a migration plan that identified three possible directions the project could take was written. These directions were evaluated with listing the pros and cons. As I saw it, the project could move in these three different directions:

1. Continue developing the prototype application
2. start fresh and utilize the SDK
3. modify the DHIS2 Tracker sample application to support the Zimbabwe use case.

I made a hard decision to discard everything that I had programmed thus far and started fresh utilizing the SDK. Although the second direction

was chosen originally, the issue of time limitation was brought to my attention. Therefore the third direction was chosen. The migration plan is attached in appendix B .

The advantage of choosing direction number 3 was to get a flying start with an application that contain some functionality. However, the advantage of a flying start was to some extent limited with an initially slow development speed and getting familiar with the code. In addition to this, the project had some funds available to employ a part time software developer that was contributing to the migration. Now we were in total two developers which resulted in rapid development.

The code from the DHIS2 Tracker did open some new doors for us developing. We branched the DHIS2 Mobile Team's Bazaar branch and started our own Zimbabwe project branch. We benefited from the existing database structure and extra functionality such as Visit schedule, Lost-to-follow-up and Single event without registration which was already developed to some extent, even though it had several bugs.

Bugs is a central word in this cycle of development. Since we were the first users of the SDK and the DHIS2 Tracker, that meant that we would face a lot of bugs. We made a deal with the DHIS2 Mobile Team that we would report any bugs faced in the DHIS2 Tracker so then they could provide a fix in the mother branch. The plan was whenever they provided a fix, then we could merge the changes back into our project branch. Since we were the only users, we were promised their full attention especially since they did not have any real use case. We realized quickly that it was faster resolving the bugs our self than filing them to the Mobile Team. We developed new functionality such as full offline functionality, possibility to register new program stages and reconstruction of the forms was generated with skip logic inside the application. Further it was contributed many bug fixes to stop the application from crashing and added basic functionality such as enabling of the back button. After we did more changes to our branch it got harder to follow the direction which the mother branch was being developed, so therefore we decided to go our own way and did not expect any further contributions from them.

After some internal discussion at UiO it was decided that now the Mobile Team were assigned to work on the Zimbabwe project because it was the only real use case. Still, not much code was delivered from them, even though they were working part time on the project. They delivered a total of nine code commits¹¹ in the Zimbabwe DHIS2 Tracker project in the period from mid November to March 2015 (when their contracts expired). All project documents and a task list were shared electronically using email and Google Docs. It became clear that they did not have the proper competence and neither did they have a thorough understanding of the project and its use cases.

¹¹<https://code.launchpad.net/~zim-dhis2-android-tracker/+junk/dhis2-mobile-tracker-android>.

Initiative was shown by HITRAC to support the project and they contributed two commits of code. Even though it was not a huge contribution, it showed that they were gaining interest in the project by working without getting paid. The second field trip to Zimbabwe was conducted when we had a stable version of the Zimbabwe DHIS2 Tracker and the plan was to interact with users in the MOHCC and stakeholders such as CHAI and HITRAC. We gained a more thorough understanding of how the existing system worked and how the users were using it in the field. The purpose of involving HITRAC was to have some software developers on the ground in Zimbabwe for maintaining the system after this master project ended. Since they recently had committed some code, we started investigating how to keep the momentum. A visit to a selection of the health facilities that were using the current system with representatives from HITRAC, CHAI and Matabeleland South Province was conducted. We briefly introduced the Zimbabwe DHIS2 Tracker and showed them the features it had. We got important feedback for improvement to implement before the pilot.

As stated earlier, we did benefit greatly from the code in the DHIS2 Tracker sample application and it gave us a flying start for developing. Functionality as Visit schedule, Lost-to-follow-up and Single event without registration was included, but was unfinished. Methods such as connection to server, logging in, retrieving objects (programs, program stages, events etc) were already developed. There was a database structure that stored meta data from the server which gave us offline functionality to some extent.

The existing offline functionality was only for enrolling patients to the program. When adding a new patient into the system while being offline it would be stored in the 'Pending Registration' tab within the application. This tab displays a list of patients that is added, but it is un-editable for the user, which is not very user friendly. Full offline functionality we needed to develop our self. This included searching for patients, adding new program stages to patients, queuing of un-pushed updates. Since offline functionality was not part of the original design, it was difficult to integrate it into the core of the application.

These core architectural decisions made it slow for further development. There was a poor database structure, which only used the SQLiteDatabase framework. By only utilizing this framework you needed to write most of your SQL code yourself for making tables, search queries etc. Further, error handling was very limited and often it only handled exceptions for the super class Exception. The limitation of error handling can be explained with lack of user feedback if something has gone wrong. For example, if loosing Internet connection while pushing or pulling data, the application would give an error message stating that 'Something went wrong'. There was neither usage of frameworks for parsing of data from the server, therefore manual parsing was done through a Java class. Manually

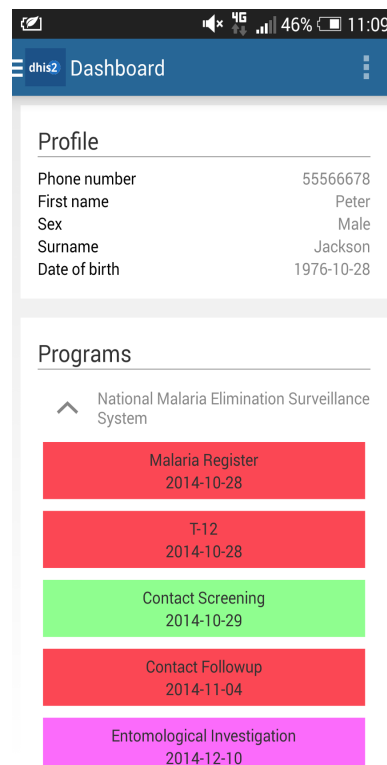


Figure 5.5: Dashboard of patient Peter Jackson in Zimbabwe DHIS2 Tracker. Color coding is similar to DHIS2 web application

parsing into JSON objects takes time and this contributed to slow development. The initially architecture of the DHIS2 Tracker (note: not Zimbabwe DHIS2 Tracker) together with the lack of functionality in the SDK forced us into hard coding in the Zimbabwe DHIS2 Tracker. This led us only to support one disease program which limited the scope of future usage. However, the requirements of the project states that it should only support the malaria programme.

After releasing the stable version of the Zimbabwe DHIS2 Tracker we learned that there were several more countries that were showing interest in the application and they were looking at different use cases. Preferably to support several disease programmes such as HIV/AIDS-, tuberculosis and malaria surveillance. It would definitely be feasible to modify the application to support multiple use cases, but due to the core architectural decisions further development would be slow.

5.4.6 Standardization

The decision to standardize the DHIS2 Tracker and remaking the Android SDK was made by the head of the research group at UiO. Because of the

dhis2 Case Investigation

Temperature (Celcius)

Presence of danger signs or signs of severe malaria?
[Please select]

Blood slide result
[Please select]

Blood spot result
[Please select]

Patient died?
[Please select]

Get Coordinates

59.9457128 10.7233841

☐ Complete Stage

Submit

Figure 5.6: Completing case investigation for patient Peter Jackson in Zimbabwe DHIS2 Tracker

emerging interest from new actors, the decision was taken to develop the standardized applications within the DHIS2 Team. For that reason, the software developer who was working part time on the Zimbabwe project was hired as a full time programmer at UiO.

The work of cleaning up the SDK was given main priority since all future Android applications now should be building on top of the SDK. Previously it had been one SDK for aggregate data capture and one SDK for disease surveillance capture. To simplify for new developers the two SDK's had now been merged. This change will have no impact on existing application that utilizes the SDK, but it does open possibilities for further development.

My engagement in this project cycle has been to communicate with end users in the pre-pilot and enrolling local programmers. Feedback from the end users has been important information for designing the standardized application to ensure the needs of the EHTs. In the second field visit to Zimbabwe, arrangements were made with HITRAC to make them contribute in this project. In the previous cycle they were working for free, but now they were getting paid to contribute to the development of the standardized disease surveillance application.

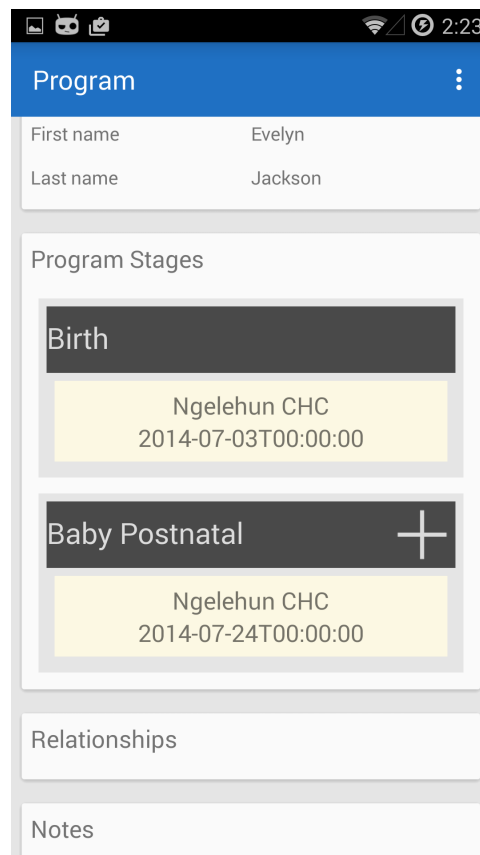


Figure 5.7: Patient dashboard for Evelyn Jackson in 'Tracker Capture'

The new standardized application for disease surveillance, 'Tracker Capture', utilize the redeveloped SDK and is built around the use case of Zimbabwe. Its being built around the Zimbabwe case because requirements such as offline support, capture of GPS coordinates and encryption of the local database are also features that other countries would benefit from. The Zimbabwe DHIS2 Tracker did have functionality to support both aggregate data capture and malaria surveillance. This was split up into two different applications; 'Tracker capture' and 'Event capture'. The former will include the disease surveillance system and should contain features in DHIS2 Tracker such as Visit schedule and Lost to follow-up. The latter will include the Single event without registration functionality in DHIS2 Tracker. The use case for the Event Capture application in the malaria project will be to capture GPS coordinates and information about breeding sites.

As stated above, both standardized applications have been developed around the Zimbabwe malaria pre-elimination project and have benefited from the feedback from users in the previous development cycle. Both Tracker capture and Event capture are being piloted in the Matabeleland South Province in June 2015. If the pilot is successful, the rest of Zimbabwe will also benefit from these two Android applications, also it may be

Registered events			
Age	Mode of Discharge	Diagnosis (ICD-10)	Status
12	Discharged	A01 Typhoid and...	✓ Sent
12	Died	A001 Cholera due to Vibrio...	✓ Sent
12	Discharged	A000 Cholera due to Vibrio...	✓ Sent
12	Died	A001 Cholera due to Vibrio...	✓ Sent

Figure 5.8: Displaying registered events in 'Event Capture'. In the Zimbabwe case, this could be showing registered malaria breeding sites

supporting other disease programmes than malaria.

In the next chapter I will discuss how the theory from chapter 3 and the literature from chapter 2 fits into this case.

Chapter 6

Discussion and findings

This chapter will present the findings of the study, with a discussion of the empirical work from chapter 5 and how the work relate to theory. Further, I will draw the relationships and identify the similarities between the literature in chapter 2 and the theory in chapter 3. The findings from this study are divided up in to categories; theoretical and empirical. First I will present the empirical findings, where the approach, my understanding and utilization of the installed base will be discussed. A discussion regarding the pre-pilot of the Zimbabwe DHIS2 Tracker will be given before discussion the theoretical ideas utilized in this study. Further, I will present the identified and emerging challenges based on our empirical work and how I seek to resolve those challenges. Finally, I will note the limitations of the research.

6.1 Practical approach

When developing a new generation of a HIS it is important to have a proper understanding of the current system, either if it is computer based or paper-based. The HIS is much more than the technical, it also involves the entire organization around it. How people that are utilizing the system, which data they are using and how they are using the data are all important aspects. As an outsider it may be hard to get a thorough understanding of all these aspects including the context it is used in. Of course, this information exists in several official documents of how the HIS is used, however, there is often a bias between how people say they are using a system and how they are actually using the system. It is also possible to gain this information in email discussions with key users, however, still the bias above exists. A third possibility is to test the pre-existing system yourself and then reflect on the technology. The problem with this approach is that the pre-existing system was a proprietary software that was running on the Windows 6.5 platform and is installed on a USD \$1.000 PDA device.

To get the proper experience it was absolute necessary to take field trips to Zimbabwe. The field trips contributed to a more thorough understanding about the context where the system is going to be used. It was also very

important to get contacts on the ground for further collaboration. In figure 5.1, it was shown that Android was the mobile platform that is most used in Zimbabwe today. However, the figure had several possible biases that were identified. Therefore it was important to get a subjective overview of the distribution of Android usage and to confirm if the figure had somewhat correct numbers.

Foster and Heeks (2013) notes that including local developers improves innovation and scaling in the context of developing countries. For this reason, it was necessary to understand if Zimbabwe had software developers that could contribute on development. My internship at HITRAC was important for this reason and had double meaning. First, as discussed in chapter 5, the Android prototype was developed in HITRAC's offices in Zimbabwe and it helped the understanding of the Zimbabwean context. Second, it was used for building a contact network and identify key stakeholders and key people in Zimbabwe.

6.2 Understanding the installed base

Here I will discuss how a thorough understanding of the malaria surveillance system was gained. The infrastructure and context it is being used in, how the system is being used by the users and how the people in the higher up positions are using the information that is being captured.

6.2.1 Infrastructure

When developing the Android prototype at HITRAC's offices in Harare, frequent power cuts and slow Internet connection were experienced. The power cuts could last up to half a hour, the Internet however, could take over fifteen seconds to load a web page. When traveling around in rural parts of Zimbabwe, it was witnessed that charging of an electronic device may be a problem in some rural areas. It was observed that one rural health facility did not have electricity for seven months. Other did, however, have electricity but it was not stable and only working for a couple hours a day. At these facilities without electricity, the health workers needed to go to the neighbors to charge the device or to charge it at home. Most health facilities had solar panels for electricity and the majority of them were working. The problem with solar power is that it does not work effectively when it is cloudy or at the evening when the sun is not at its strongest. In some areas where malaria was not very common it was found that the Environmental Health Technician (EHT) did not bring the PDA to work and had forgotten it at home when recharging it. There was one thing they did not forgot at home, and that was their personal smart phone. The Android distribution in Zimbabwe was found to be high and even those EHTs in the rural areas had a smart phone with an Android version ranging from Froyo (version 2.2) to KitKat (version 4.4). At the time of visit, the latest Android version was Lollipop (version 5.0), but only a few percentage of phones world wide

had this version, thus KitKat is seen as the most used and stable version. On the other hand, Froyo is old and is not very common, having about 0.5% of the distribution world wide¹.

Internet coverage in Matabeleland south province was mixed. The urban areas such as Beitbridge and Gwanda had good connection, but the rural areas had limited or no connection. At one rural health facility there was Internet connection if you went up in the valley. At another rural health facility a few kilometers north of the South African boarder, there was Internet connection, but only by the South African phone operator Vodacom. The EHT needed to buy airtime on this network, which is a bit difficult to get on the Zimbabwean side of the boarder. The PDAs contain a SIM-card from the network provider Econet. CHAI is responsible for refilling the devices with airtime and it is provided USD \$1 each quarter per device. We can see that Zimbabwe is dealing with the same poor infrastructure as most other developing countries. On the other hand, the distribution of smart phone and tablets was considered as high, just as figure 5.1 shows.

6.2.2 Practical usage of the system

The installed base for malaria surveillance comprises of a computerized system and a paper-based system that mainly functions as a backup system. However, it was observed that the health workers actually valued the hard copies. It was somehow hard to grasp the true reason why they valued hard copies so much, and they gave various reasons such as:

1. if the computerized system was to break down, the data was not going to be lost if they have it on paper
2. The data was reported in from a distant location, or a patient is being referred from another facility, which does not have a PDA, then the paper system is working like a temporary system before it is being entered into the computerized one.
3. It is an old habit of entering the data on paper.

When people are referred from other health facilities, they are registered into the new facility on their PDA device. Communication between these two health facilities is done either through phone calls or utilizing the WhatsApp² messenger application.

The PDAs were distributed to one EHT in each health facility which participates in the malaria pre-elimination programme. However, in urban areas of Matabeleland South Province, it was found that an EHT was responsible for two health facilities because they were lacking manpower and funds. Two identical PDAs were distributed to the EHT, however they were

¹<http://developer.android.com/about/dashboards/index.html>.

²<https://www.whatsapp.com/?l=nb>.

manually configured for the two different health facilities. The EHT stated that there was no problem distinguishing between the two PDAs, because he had labeled them.

The EHT is solely responsible for entering data in the PDA system for malaria patients coming into the facility and to do the following up routine as described in chapter 5 on page 44. The EHTs often has a motorbike for when visiting patients at their homes. The motorbikes are donated from a global aid agency, but its intended usage is for HIV/AIDS and Tuberculosis (TB). These diseases generate more money from the aid agencies so they can afford it. However, the motorbikes are sometimes used for malaria purposes but it is only “allowed” if there is a HIV/AIDS or TB case close by so they do not waste fuel on not targeted diseases. Regular bicycles are also donated from aid agencies which can be used for any purpose.

When the EHTs is going in the field the GPS functionality is very important for capturing accurate coordinates of the patients household and the breeding site where the patient suspects being infected. There was found some difficulty capturing these breeding sites on the PDA. Some EHTs stated that to capture a breeding site they needed to create a new ‘dummy’ person in the system only for completing the Entomological investigation form. The GPS functionality on the PDA device was tested and was found quite accurate, only missing the target by a few meters. Entering data on the PDA device was done with a small pen. Entering data with the pen was something that they have gotten used to and did not feel that it was any problem. One EHT had lost his pen and had to use a match to enter data on the device and it worked as a perfect replacement.

6.2.3 Information usage

The information that is captured on the PDA device is put into a vertical system and the data needs to be manually merged into DHIS2 at district level. The people in the higher up positions can thus access the data captured through the DHIS2 interface. The intended information usage is to better distribute vaccines and other supplies to the places that need them most. However, this was not the case everywhere. At one district hospital, they did not contact the provincial level if they detected a outbreak or noticed a shortage of medicines or other supplies. It was stated that they [the provincial level] did not have any funds to provide extra supplies anyway, so it was not worth the extra workload to notify them.

Today, the health care workers at the district level are calculating a threshold for detecting malaria outbreaks. The threshold consists of five year monthly statistics of confirmed malaria cases. If the current month has a higher number of confirmed cases than the threshold, it is classified as an outbreak. Currently they are calculating thresholds manually at district level with the data that is submitted from health facilities. If the monthly numbers exceeds the threshold, they will be given feedback

through a phone call from a higher level that there is an outbreak. The district level is expected to inform the provincial level to delegate some extra funds so they are able to provide extra supplies to the area of outbreak. For the reasons of pre-elimination, information usage is a key factor to restrain and minimize the transmission of malaria. Therefore when an individual has been confirmed as malaria positive, it is important to check the other people in the same household. The EHT have to make the decision if the household needs preventive treatments, such as an indoor residual spraying (IRS) or if its enough to provide bed nets. Information of the captured breeding sites is being used to eliminate them using the larviciding technique or spraying the mosquitoes.

6.3 Pre-pilot of Zimbabwe DHIS2 Tracker

The pre-pilot of the Zimbabwe DHIS2 Tracker was conducted in February 2015. As stated in section 5, the intention was to roll out the software in June of 2015. The purpose of the pre-pilot was to get feedback from users at several health care institutions, and at the same time understand which limitations and strengths the pre-existing system had. To understand the system, a five day field trip was conducted in the Matabeleland South Province where a random selection of health facilities and district hospitals were visited. The visit contained health care institutions both in the urban and rural areas of the province.

The Zimbabwe DHIS2 Tracker contains the existing functionality of the pre-existing system and has several extra functionality such as:

- Users are able to work with offline data storage
- Able to capture breeding sites without linking to patient
- Generate visit schedule for the following up routine
- Display user feedback when uploading data
- Able to link relationships between patients

It has also several advantages such as

- It is able to communicate with the national DHIS2 instance
- The application is on the Android platform
- A flexible approach. Do changes once at server, and all the devices are able to download the changes
- The application is based on DHIS2's permissions. Users have access to the data for their health facility (or facilities)
- Has a flexible user interface which adapts to every screen size

The application was tested by users on an Android smart phone with a 4.7 inch screen to give them the feeling of how it works. Even though the application is targeting Android tablets, which have a screen size bigger than 4.7 inches, the users seemed to be able to navigate through the application. Some of the users stated that they recognized the forms with the identical data elements. Several EHTs had a personal Android smart phone so they felt comfortable using a touchscreen device. Further, the GPS functionality was tested and a comparison was done between the two systems. A spot was chosen in front of a building of a rural health facility that is easily recognized on the map. It was a clear blue sky and there was nothing that blocked the signal.

Figure 6.1 below shows that the Zimbabwe DHIS2 Tracker hits the target spot on, but the PDA missed with a few meters.



Figure 6.1: This compares the difference in GPS technology between Android based system and PDA system. Android-based system is represented in green and PDA-system represented in red.

A few meters margin of error is okay, but the reason why the Android smart phone was more accurate can be that it can utilize newer technology such as A-GPS and regular GPS. This newer technology may contribute to a more precise measurement.

6.4 Reflection upon theory

When developing the Android applications it has been important to keep in mind the theory from Heeks (2002) regarding the design-reality gap model to see if it can contribute to a successful adoption of the system. As stated in

chapter 3, the design-reality gap model is based on the ITPOSMO acronym. The acronym consist of:

- Information
- Technology
- Processes
- Objectives and values
- Staffing and skills
- Management systems and structures
- Other resources

Next I will discuss how each of these elements of this model has been taken into account when designing the new system, but also linking it to the installed base. In the development process it has been challenging to take the correct decisions which contributes to closing the gaps between reality of the pre-existing PDA system and the design of the Android based system.

Information usage and flow

This dimension compares how the information quantity, quality and the information flow of the systems (Heeks 2006).

Information quantity is nearly the same since both systems are using the same forms and the data elements that are within them. The forms in NMCP are developed by the MOHCC in such a way to ensure high information quality. However, the Android based system utilizes some extra skip-logic, such as male patients do not get asked if they are pregnant. Further, option sets and yes or no-questions are dominant in the forms to limit the possibility for the user to make mistakes.

In the pre-existing PDA system, information flows straight into a vertical system that does not share any information, automatically, with other systems. On the other hand, the DHIS2 Tracker are able to communicate with the national DHIS2 instance. This can lead to better data quality and make the health care sector more effective (See processes below). When data goes straight into the national DHIS2 instance, it means that the server can also provide statistics, graphs, charts, maps and calculated thresholds for the users

Although these features will not be apparent in the pilot of the Android application, but it enables opportunities for further development where greater usage of data can be utilized. Today graphs and charts are made by the health workers themselves by hand and put up on the walls. These drawings shows that the health care workers in Zimbabwe value the data that they collect and utilize it in their daily work. Since graphs and charts

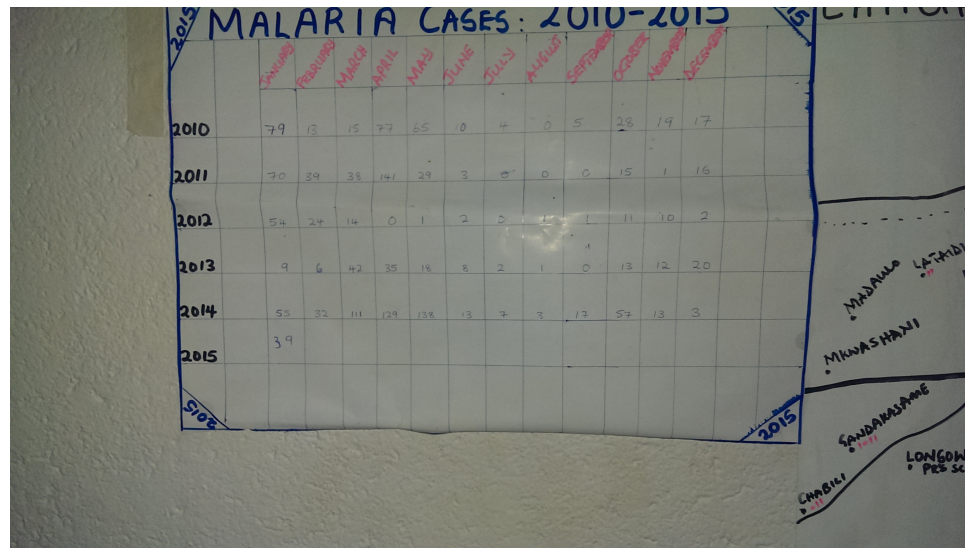


Figure 6.2: A chart that shows the aggregated malaria data at one health facility. To the right one can see some of the hand drawn maps.

are not provided from their current HIS, we recognize this is a local improvisation of the HIS, just as described by Heeks (2006).

So from this we can see that information usage in Zimbabwe is different from other developing countries, where information usage is more used at higher level, such as districts, provincial and Ministry. In Zimbabwe the health workers at facility level value the data that they collect and transform it into charts and graphs.

Technology

This dimension compares the technologies of the installed base and the new system. It consist of software, hardware, technology for communication and other health care technology present (Heeks 2006).

The choice of technology is different on the two systems. The pre-existing is on Windows 6.5 platform and the new one is designed for the Android platform. Android was found as the most common platform used in Zimbabwe by a quantitative study. During the second field visit to Zimbabwe, these results were found to be legitimate. Android was a common platform among the people in the big cities as well as those living in the rural areas. When visiting some of the rural health facilities in Matabeleland South Province, there was a EHT that owned a seven inch Android tablet and was using it as his personal phone. At another rural health facility, the EHT had a Samsung Galaxy smart phone. A recommendation of different Android tablets has been provided to the Provincial Medical Doctor in Matabeleland South Province and they are responsible for acquiring these devices. The recommendation plan is provided in appendix C. San-

ner, Roland and K. Braa (2012) argue that one should do a early lock in if you are utilizing the health workers personal devices. However, Sanner, Roland and K. Braa (2012) concludes with that utilizing privately owned devices may be required for making an ICT system scale in low resource countries.

Therefore we have gone for a “hybrid” solution that utilizes the installed base of smart phones, while targeting Android tablets. The application does have a flexible view that adjusts to every screen size and enables a hybrid solution approach. The intention is that the EHTs is going to use the application on the tablets, but if they break down or stop working in any way, they are able to use their personal Android device as a backup. Android as an open platform supports many different phones and tablets and therefore can be seen as a good platform. In contrast, the PDAs runs on the Windows 6.5 platform which is not common and it is neither open source. The Windows 6.5 platform stopped being supported as of 1. August 2013. This shows that there is a gap between the two systems here.

Furthermore, applying newer technologies contributes to more accurate data, which was shown for capturing GPS coordinates. Applying newer technologies also implies usage of newer frameworks that can contribute to higher data security. Data security is a crucial when handling sensitive information, such as patient specific data in this case. Since the PDA's do not encrypt the data on the device, and neither deletes the data after it is being posted, this opens up for a serious risk if the device is stolen. Moreover, the PDA's post their data without any encryption, just in clear text. On the other hand, the Android application posts all data over the HTTPS protocol, thus making it more secure. Further, an encrypted database is soon to be implemented. When the database is encrypted, it limits the risk of data breach if a device gets stolen.

Processes

This dimension compare how information is being handled and how decisions is taken (Heeks 2006).

Utilizing the Android application would put data straight into the national DHIS2 instance. This would lessen the work on the data clerks at district level, since they now would not have to merge data into DHIS2. Data quality can here be improved, eliminating the risk of the clerk making mistakes when merging. The clerks will still be needed in their jobs, because the paper-based system is still crucial component in the HIS. If the computerized system breaks down, the EHTs will report data on the paper forms and submit to the district where it is put in to DHIS2.

J. Braa and Sahay (2012) note that having all the health data in the same database helps the decision making. As noted in the Information sub section above, the information from the PDAs is going straight into

a vertical system, where the data entered from the Android application is going into the national DHIS2 instance. The intended information usage is to better distribute vaccines and other supplies to the places that need them most. However, this was not the case everywhere and there was a design user-reality gap at one district hospital. As noted before, all the processes are not being completed when one EHT noticed that it was a shortage of supplies, because the provincial level did not have the resources anyway.

Objectives and values

This dimension compare the objectives of all stakeholders within the project and their values (Heeks 2006).

In the installed base for malaria surveillance there are several actors identified. First of all, the users that are benefiting from the systems (the patients), the EHTs and other health care staff that are utilizing the system in the health care sector. Second, there is the MOHCC which also benefits from the system by gathering malaria data for keeping the people healthy. Furthermore their goal is to eliminate malaria in whole Zimbabwe. Finally, there is external actors, such as CHAI. As a nonprofit organization, they stated that their goal to help the MOHCC to eliminate malaria.

For the Android based system, the same actors as above are part of the system, including the University of Oslo (UiO) and HITRAC. UiO has as its goal to help the MOHCC to help their population by introducing a mobile extension for the DHIS2 software. One can argue that they have a vested interest in spreading the DHIS2 technology. HITRAC is a nonprofit organization that seeks to train people in health informatics. They will be included in the development process of this system. The standardization process of the Zimbabwe DHIS2 Tracker has made it important to include HITRAC in the development process. When new actors express their interest in the project, it exerts a risk that can get the project out of the Zimbabwe use-case.

We can thus see that there is not a very large gap in this dimension between these two systems, but the risk of standardization when new actors gets involved is highlighted.

Staffing and skills

This dimension compare the staff numbers, their technical and health care skills needed to for utilizing the systems (Heeks 2006).

WHO³ states that there is a shortage of over 50 percent of doctors, midwives, laboratory, and environmental health staff in Zimbabwe. At each health facility there is at least one EHT and a nurse. To be qualified for a

³<http://www.who.int/workforcealliance/countries/zwe/en/>.

job as a EHT you need a diploma from a learning institution that teaches health informatics. Therefore the people that are working as EHTs have both a technical and a medical understanding. Currently they are using the PDAs as a technical system, showing that they are able to use computerized systems. As stated in technology sub-section above, Android usage in Zimbabwe is found to be common. Further, it seemed that the health care staff in Matabeleland South province were used to utilizing technology. This contributes to reduce the gap between the skills needed to utilize the new system.

A change to the Android based system will not require any increased numbers of staff. In fact, it may the opposite and contribute to an increase of efficient processes that leads to a more automated system.

Management systems and structures

This dimension compares the different management systems including formal and informal structures (Heeks 2006). It includes structure of the organization and how it is being managed.

Because of the lack of IT skills within the MOHCC they have requested donor support from external actors, such as CHAI. Since the MOHCC has already introduced DHIS2 as their main HIS, therefore they will also benefit from UiO's support and the DHIS2 community. In the pre-existing system there exist formal agreements between CHAI and MOHCC. In the new system, formal agreements between MOHCC and UiO exist, and UiO has a informal agreement with HITRAC to contribute to the development of the standardized applications.

Other resources

This dimension includes resources, such as time and money is being used. This dimension compares investments, ongoing expenditure and other health care resources (Heeks 2006)

This project has a collaboration with a large aid agency that contributes with health investment over several years. The investment in this context will be acquisition of Android tablets plus accessories. The accessories may involve some protection for the device, a keyboard for easier data entry and a battery pack. Initially, this project does only have an one year contract, but if the pilot is successful there is a possibility for an extension for funding in a longer time period. Since the investment is fully funded by the donor, there is no gap between investment and budget. However, the ongoing expenditure may be a problem. It was stated that the PDA's use USD \$1 per device each quarter. It is hard to predict how much money that the Android based system will use each quarter, but to be more efficient than the PDA system will be difficult. Here it may emerge a gap between the two systems, but this is something that the pilot will show. Further we recognize that

training of staff is necessary and this costs both time and money.

From discussing the dimensions of the design-reality gap model, this study agrees with the critique offered by Heeks (2006) which states that the dimensions should not be seen as static, but as dynamic, since dimensions such as funding depends on the projects success.

6.5 Information flow in vertical system versus national HIS

As stated before, the PDAs posts data into a vertical system. This approach has created challenges that the new Android based system seeks to resolve. The Android based system is integrated with the national HIS in Zimbabwe. Below I will discuss if the new system resolve the identified problems. Further I will also discuss the new challenges that emerge when introducing this system.

6.5.1 Resolving problems

The introduction of the Android based system seeks to resolve the following problems that Zimbabwe are suffering from and that the PDA system has contributed to. Below I will discuss which strategies the Android based system used to resolve those problems.

Fragmentation of HIS

The issue of fragmentation is apparent in most countries in the Global South, and Zimbabwe is not an exception. The PDA system is putting data straight into a vertical system, this contributes to fragmentation of the HIS in Zimbabwe. On the other hand, the Android based system puts data straight into the national DHIS2 instance, which contributes to de-fragmentation of the HIS.

However, the PDA system has manual processes, such as a data clerk at the district level who merges data from the installed base malaria surveillance system and enters it into the DHIS2 web application.

Poor data quality

As noted in chapter 2, fragmentation leads to poor data quality (J. Braa, Hanseth et al. 2007). Manually merging data between two systems can lead to poor data quality, because it enables the risk of the data clerk making a mistake. However, this study does not provide any evidence to support this argument, but it is logical. Further, the usage of the paper based system if the computerized is broken will enable higher burden on the data clerks thus higher risk of making mistakes. The risk of the Android based system

for breaking down is seen as the same as the PDA system.

As Shrestha and Claude Bodart (2000) notes, reporting of inaccurate data leads to poor data quality. For resolving this issue, we have included a more thorough skip logic than the ones that are included in the current forms. Also by using DHIS2's design, patient details have been moved away from the forms and into the enrollment part of the application. By utilizing this design we can restrain the reporting of inaccurate data and enable re-use of captured patient details in more than a single program.

An improvement for the Android application can be to include DHIS2's functionality for minimum and maximum values on data elements. However, this is not an requirement as for now, since the MOHCC has staff to ensure the data elements are within limits.

Poor information usage

Introduction of an mobile based HIS will not necessary have a direct link with better information usage. As (Garrib et al. 2008) note, there is a poor tradition of information usage for decision making in developing countries. However, with the introduction of a DHIS2 based mobile application the data is now posted straight into the national HIS. This contributes to facilitate for decision making.

Issue of disease surveillance

The introduction of an Android based application for disease surveillance will enable new possibilities and opportunities. We have shown evidence that utilization of new devices and technology contributes to more accurate information for collecting GPS coordinates. The release of an Android based disease surveillance application can, if it is perceived good enough, emerge as a new flexible standard for all disease collection on Android devices. This is if the SDK is flexible enough for new modules to be added locally to address the changing needs.

Data security

The existing system is very poor at data security. As noted in section 6.4, it has no encryption or usage of HTTPS when posting data over the Internet. This contributes to a large risk of sensitive data being stolen.

The Android based system has encryption of the local database as a priority. Furthermore, it always posts data over HTTPS, thus ensuring a secure connection with the server. Thus we can say that the Android based system is a more secure solution than the PDA system.

6.5.2 Emerging challenges

The introduction of this new technology opens up for new challenges. It is important to note that the challenges identified below is not only restricted to our introduction of an Android based system, but are existing, ongoing challenges that Zimbabwe faces. To handle these emerging challenges we apply some of the theory presented from chapter 3.

New database

It was stated by a research consultant working with the DHIS2 team that a government should not mix aggregated data and patient specific data in the same database. There are several reasons why to do this. The Tracker module handle patient specific details, therefore a larger focus is needed on data security. Also as unfolding projects one can slow down the other. In the future when these modules are stable it will be possible to include them in the same database. However, for now, a new database needs to be created.

As noted in chapter 1, there is a common problem in developing countries today with the necessary IT competencies. Therefore outsourcing maintenance and operations of a server is common. The Zimbabwean MOHCC is lacking the necessary IT skills to be in control of all their data. This raises the question: *Who should take ownership of the new database?* Of course, the MOHCC should take ownership of the database, however as noted, they lack capacity and skills to do so. Building capacity within the MOHCC is a good strategy, but this takes time – and the pilot of the new system is in June. Therefore outsourcing the ownership to other actors is a possibility and to collaborate with organizations such as ZimHISP or CHAI. The outsourcing is only a short term plan and when the the MOHCC has built its capacity they should take ownership of the database.

Today there is an existing and, ongoing, innofusion process which seeks to address a similar problem. ZimHISP has been provided office space within the ministry to have a closer relationship with the MOHCC for technical assistance. It can be seen as an innovation of work processes and diffusion of technological knowledge within the MOHCC. Further, as an improvement, there could be introduced a (easier) framework for server maintenance, so that it could be less cumbersome to handle for the 'not so technical people'.

Aggregated versus patient data in the HIS

As stated above, the MOHCC should not mix aggregated data and patient specific data in the same database because it is not the same "type" of data. Nevertheless, it is just as important to have the patient specific data in the aggregated database. As stated in chapter 2, the aggregated HIS can not deal with patient specific data. Therefore for resolving this problem, it is in-

troduced a set of indicators that enables transforming patient specific data into aggregated data. Indicators are able to calculate a coefficient between two data elements. It is normal that the coefficient should be matching a target number. An example of this can be an indicator that calculates immunization of children below five years. If the goal is set to 80 percent, the coefficient between the number immunized divided by the number of children below five years should match, or be above the goal.

We can see that the theory on flexible standards from J. Braa, Hanseth et al. (2007) have some similarities with the indicator set that is included in the malaria pre-elimination project, since it can not be static, but it is ever-changing to support local needs.

Training users for the new system

Training of users is an important aspect when introducing a new HIS. Shrestha and Claude Bodart (2000) highlights the importance of training of users and claim that it leads to better data quality. However, training of users is an expensive task that takes both time and money.

Before starting training the users, it should be a training of trainers to lessen the cost on external trainers, but also to building capacity of the locals. When trainers are being taught, the trainer is not able to render the exact information when training the users. The concept of innofusion relates to this process because trainers need to use their personal experience to teach the users, thus innovating and diffusion of the knowledge.

The 'synchronization problem'

In this project we went for the "hybrid" approach, and this opens up for some risks. When opening up for a hybrid we allow several devices being connected to the same server, even if one user account is used. The intention for this hybrid approach is: If the Android tablet is broken, then the EHTs are able to use their own personal Android device (if they have one) for data collection. If the EHT, for some reason, starts to use both devices without synchronizing with the server on a regular basis, it can lead to the 'synchronization problem'. This problem is when two devices are syncing with the server, but the server does not know which of the device has the latest version of the data. The problem occurs when two devices are pushing data of the same patient and then the server will store the data that is pushed last. Thus the server has no idea which data is the newest.

However, it is important to note that this problem also exists in the pre-existing system. If the PDA device runs out of power, the EHT needs to enter the data manually on paper, and thus the 'synchronization problem' occur.

6.6 Integration versus Interoperability

In this section I will describe the why it is different with an integration approach versus an interoperability approach. As stated in sub section 2.3, there is a key difference between these two approaches. The key difference argue that if it is by intention in the design for systems to communicate with each other; it is integration. And on the other hand, if the system is not designed to communicate with other systems, it is interoperability.

In this project we have clearly gone for a integration approach where specific code to make the two systems communicate through DHIS2's API was written. The DHIS2 Web API provides an easy interface that supports the existing communication standards and the API is well documented on DHIS2's website. In addition to this, DHIS2 has recently been accepted as Zimbabwe's new national HIS. For these reasons including the time limit of 18 months, the integration approach was chosen.

If time was not a factor, an interoperability approach could be a good solution. If the Android application had communicated over shared standards and was developed a gateway between DHIS2 and the Android application. This could have contributed to an interoperability approach, but not only against the DHIS2 software, but then it also could have supported any other information system. In practice, if the conditions are optimal, the Android application could be used world wide. However, to rely on the poor infrastructure that characterizes most developing countries to deliver real time health data may not be a good idea. The scope and requirements of the Zimbabwe project is not for going world wide, it is just to support the national HIS for malaria surveillance. Further, development of such a system would require a longer time frame, including an agreement over shared standards. On the other hand, DHIS2 as a growing HIS will give the standardized Android applications more contexts to work within and new disease programmes to work with.

6.7 Technical approach

In this section I will discuss how which strengths and limitations that this technical approach gives. This technical approach that was utilized is an application based solution type. Further I will discuss how the application based solution is affected by the chosen platform and the installed base in Zimbabwe.

6.7.1 Application based technical solution

In section 2.4 I provided the different solution types of which a mobile phones can utilize. In this section I will discuss why a "native" application based solution is the best choice for this project.

This project included requirements such as:

- Develop an application that is linked to DHIS2
- Capture patient specific information
- Store the information secure on the device
- Utilize the forms provided from NMCP

The IVR solution type is not applicable for this type of project because it is not optimized at patient specific data collection, nor does it store data on the device. The SMS based solution type is neither applicable for this type of project because when collecting patient specific data, you easily go above 160 characters. Further, this project need an user interface for displaying the skip-logic forms. The browser based solution would be possible, but client storage is limited thus making this solution type not applicable. Further, browser incompatibility is another risk that needs to be taken into account. The application based solution type takes advantage of the user interface on the device to display the skip-logic forms. Further, secure client storage is available through a local encrypted database.

As Sanner, Roland and K. Braa (2012) notes that when choosing the application based solution type, there are two technologies the application can rely on for data transport; SMS or GPRS. Even though a SMS-based data transport is more robust and works where there is no access to Internet, the GPRS-based transport were chosen. As stated in chapter 5, 80 percent of the population in Zimbabwe is covered with mobile Internet. Furthermore, as stated in chapter 2, most developing countries are investing in mobile infrastructure.

As presented on page 16, there is two approaches to the application based solution type; "native" and "non-native". Now I will argue why a native approach was chosen.

Android is the mobile operating system with over 50 percent of the user mass. The operating system that is closest to Android is the Series 40- (S40) platform on Nokia devices, without touchscreen, has over 20 percent of the user mass (Figure 5.1). When Android is such a dominant platform, then it is really no need for going non-native utilizing Apache Cordova. Going non-native would increase risk and use of resources to support all platforms rather than focus on the largest platform. Furthermore, there already existed an Android software development kit (SDK) for DHIS2.

For these reasons, a native application based technical solution was chosen.

6.7.2 Addressing disadvantages of the approach

When choosing Android as a platform it was known that it may have some limitations. However, these limitations are not only technical, but also socio-technical problems.

Sanner, Roland and K. Braa (2012) has identified six disadvantages with the application based solution type:

1. First installation: Are the devices going to be manually configured or are the users going to do it?
2. Users are able to delete the application
3. Setup of mobile data can be difficult on some devices
4. Are users able to update the application whenever new updates are released?
5. Issue of navigating to the application to launch it
6. Control cost and limit mobile data usage of other services

Regarding the two first disadvantages, there is possible to make an arrangement with the mobile device manufacture to pre-install the application and make it undeleteable. There is also possibility to install an application that prevents the user from uninstalling other applications. If the application is not pre-installed, it is best to do a manual configuration, thus lessen the technical burden on the end user. Setup of mobile data can be difficult, however, this should be resolved when manually configuring the devices. When utilizing private devices, it is expected that this is already configured. Number 4 highlights the issue of updating the application. Users are notified if there is an update through the Google Play Store application. The real disadvantage, as I see it, is the cost and stable Internet when updating the application. The issue of users struggling to navigate to the application can be resolved by making a shortcut to their home screen on the device. To control cost and limit data usage of other services may be the largest disadvantage of this solution type combined with this platform. It is hard to predict how much data the Android based system is using, but to match the pre-existing system with USD \$1 per quarter of year will be tough.

The other services, such as unintended usage of the devices are identified as a larger risk. However, it is important to note that this problem does also occur in the pre-existing system, but the Windows 6.5 platform does not have the same variety of applications as the Android platform.

Chapter 7

Conclusion

7.1 Concluding remarks

This thesis seeks to address challenges related to the development process of a health information system (HIS) in the context of developing countries. Furthermore it seeks to understand which theoretical ideas can be utilized to make HIS being successfully adopted. It has introduced theories to understand how to meet requirements of the users at the lowest level, and at the same time facilitating for organizational growth.

The empirical work of this study includes development of several Android applications that seek to improve the pre-existing tool for malaria surveillance. Android was the chosen platform since it provides new frameworks, technology and cheap devices are accessible. In contrast, the pre-existing system is on a discontinued platform installed on a expensive device. The empirical work has gone through four cycles. Where three of the cycles involved development of Android applications, the first cycle included work to customize the paper-based forms provided by the National Malaria Control Programme (NMCP) in Zimbabwe. My customization was unsuccessful because the MOHCC simultaneously did their own customization to optimize the forms for handheld devices. The second cycle included the development of the Android prototype application. This cycle was successful since it generated interest from stakeholders with the NMCP in Zimbabwe. Further, the work from this cycle gave us contacts with the stakeholders for closer collaboration. At the end of the second cycle I learned that the DHIS2 Mobile Team were developing a software development kit (SDK) and a sample application for patient specific data collection. The third cycle is based on the work from the DHIS2 Mobile Team, and further I developed the Zimbabwe DHIS2 Tracker along with a part time programmer, DHIS2 Mobile Team and HITRAC. The Zimbabwe DHIS2 Tracker aimed at being piloted in Matabeleland South Province, but already in the pre-pilot when final user requirements were collected, the decision to standardize the application was taken. Thus the cycle was cut short and it is unknown if the cycle had been successful or not. Since new actors had expressed their interest in the project, this decision forced us into the fourth cycle

which included a standardization process of the Zimbabwe DHIS2 Tracker. The standardized applications; Tracker Capture and Event Capture, was built around the use-cases from the Zimbabwe project. Experiences gained from previous cycles were important in the design of these applications, as well as the user requirements from the pre-pilot. Both Tracker Capture and Event Capture is being piloted in June 2015.

Based on these cycles, I will answer the research questions as provided in chapter 1.

What theoretical ideas can be utilized to understand the development process of a mobile Health Information System in a country in the Global South?

In this study the design-reality gap model has proven to be useful for developing an information system in such a context. It is important to note that the critique offered by Heeks (2006) who states that the dimensions of the model should not be seen as static, but as dynamic was found to be legitimate. This model was useful for linking the new system with the reality and recognizing the ever-changing environment. A tighter link between the new system and the reality was achieved through utilizing the three aspects as presented by Heeks (2006); methods, techniques and roles and competencies. A participative method which included collaboration with stakeholders was utilized. CHAI and health care staff from Matabeleland South province were involved. A participative method provided useful information, both on important documentation, such as the touchscreen optimized forms, and how the application is being used in practice. Two techniques were used; first-party observation and rapid prototyping. First-party observation was done during both field trips to Zimbabwe to observe the socio-technical reality. Rapid prototyping of the Android application was useful for receiving precise and constructive feedback from the users. Some health care workers in Matabeleland South Province had an important role in this project as testers, being "hybrids", since they work with malaria pre-elimination and have a strong technical understanding.

This utilization of the design-reality gap model has proven to be useful which is compounded by the positive feedback from the users during the pre-pilot.

How can we understand the challenges of meeting user needs at the lowest level and support innovation for system growth to support users at other locations?

Meeting user requirements has been important in this study. It has been experienced in this study that the users often know which features they need to do their work efficiently in context. Not all wishes were fulfilled, such as translation in the application for supporting different tribal languages. In Zimbabwe there are over ten official languages,

including English. If one tribal language is supported, then we also need to translation to the rest.

Also some organizational change has been necessary for making the system scalable and support users in other positions. For supporting the growth we have introduced Android as a platform for the new data collection applications. Introduction of a new platform exerts a challenge of how it is being perceived at the lowest level. However, in the pre-pilot of the Zimbabwe DHIS2 Tracker, the EHTs were positive to the change and several EHTs were familiar with Android. The introduction of the Android based system also changes the information flow, now it is being put straight into the national HIS. For users at other locations, such as the health care staff responsible for merging data from the pre-existing system into DHIS2, this system exerts a less burden on them. They have to deal with less information, but their job is still needed if the paper-based system is utilized for some reason, then they need to merge data into DHIS2. For the people in the top positions, the Android system means facilitating for better decision making, because of the improved data quality and accurate data.

When several new actors expressed their interest in the project, it was taken the decision to standardize around the use-case from the Zimbabwe malaria pre-elimination programme. The standardization approach in the final cycle highlights a tension between meeting user needs and organizational change in development. A standardization approach means that people at other locations within the DHIS2 community can benefit from the work in Zimbabwe. However, if the new actors are larger than Zimbabwe and they generate more money into the standardization project, this may present a new challenge. If the use-case is moved further away from the needs of Zimbabwe, a challenge may occur.

In the case of Zimbabwe, what challenges arose and what strategies were used to address them?

The standardization problem is a challenge that may occur, therefore we needed to address this challenge. We engaged a local software development company, HITRAC, in the development process of the standardized Android applications. If gaps starts to appear, HITRAC is able to fork the project and further develop the application closer to Zimbabwe's needs.

7.2 Future work

Research could be conducted to evaluate if the implementation of the Android based system has been successfully adopted and is a sustainable solution. Further, this research should evaluate if the application based approach has been successful and seek to resolve any risks that is identified. The research could also see if there has been any the local adoptions of the system to make it better fit in the context of Zimbabwe. Also, as Foster and

Heeks (2013) notes, there is a need of more studies aimed at scaling of systems in developing countries.

Further, technical work need to be conducted to continuously develop the SDK to support new applications and be the basis of the Android platform for DHIS2.

Appendix A

Appendix: Letter of invitation

The letter of invitation is attached in this appendix.

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Reference:
Ministry of Health and Child
Care
P O Box CY1122
Causeway
HARARE

06 February 2015

University of Oslo
Health Information Systems Programme
Department of Informatics, Global Infrastructures Group
P.O 1080
Blindern 0316
Oslo
Norway

Att: Professor Jorn Braa

REF: INVITATION TO PROVIDE TECHNICAL ASSISTANCE FOR DHIS2 ROLLOUT:
11-27 FEBRUARY 2015.

As you may already know, the University of Oslo's Health Information Support Programme (HISP) has been providing technical support to the Ministry of Health and Child Care Zimbabwe under Global Fund agreements. The technical assistance goes towards the sustainable implementation and roll out of DHIS2 and electronic patient management systems.

As a continuation of this support, the ministry hereby invites the following members from Oslo University:

Surname	Name	Nationality	Passport Number
Matavire	Rangarirai	Zimbabwean	
Fjelstad	Erling	Norwegian	
Heywood	Arthur, Brookes	South African	
Braa	Jørn, Anders	Norwegian	
Jolliffe	Robert, Mark	Irish	

Your cooperation will be greatly appreciated.


Brigadier General (Dr) G. Gwinji

SECRETARY FOR HEALTH AND CHILD CARE

SECRETARY FOR HEALTH & C/C
(PRINCIPAL DIRECTOR CURATIVE
SERVICES)

SECRETARY FOR HEALTH & C/C
(PRINCIPAL DIRECTOR CURATIVE
SERVICES)
09 FEB 2015
P.O. BOX CY 1122, CAUSEWAY
ZIMBABWE

Appendix B

Appendix: Migration plan

B.1 Context

The Zimbabwean malaria-project is now moving into a global context. There are more interest in the project from several actors and thus we needed to involve more people into the project. We have involved the DHIS mobile team and another professional Android developer that have experience from developing applications for DHIS. Currently we have a working online version application, “Disease Tracker”, specialized for collecting individual records for multiple program stages in the DHIS-tracker. Disease Tracker is connecting through the DHIS web API and has the same work flow as the web application, so that you get the same “DHIS feeling”. It is a flexible app that works on different servers and can also work for several different health programs such as tuberculosis or maternal health. A couple of months after I had started to develop the Disease Tracker, the DHIS mobile team started a project in developing a mobile tracker SDK. The mobile team has involved four professional developers and one tester to work on this project. The tracker SDK is a platform independent and a generic solution for handling the requests from and to the server, including all the models(representation of a program, program stage, tracked entity etc), and abstract manager-(Record manager, GPS manager, Network manager) and JSON serialize classes. The mobile team has also provided an Android tracker application that does utilize the Tracker SDK. Some further months into the development phase, I was made aware of the Tracker SDK and the progress they had made. Through the head of the DHIS mobile team, I was introduced to the lead developer of the Tracker SDK. The lead developer showed me how the SDK works, how to get it, and how to include it in my project. At that time the SDK did not have all the functionality that the Disease Tracker had, but it was still in rapid development. I tried to look into migrating, but the structure of the code was totally different, and it would take too much effort to changing my structure to support the SDK. I was currently working in Zimbabwe, and after some discussion with my supervisor we concluded that it would be better to have a working solution to present to the people in Zimbabwe, than start going into another direction and possibly ending

up without a working solution. As I see it right now, the project can move in two directions: Continue the project on my own way, doing everything manually and creating everything myself, or vi can start utilizing the DHIS Android SDK where things like log in, offline support and fetching of all data from the server is already included. Ideally, the best would be to find a middle way that could use my own existing code and get the necessary support from the SDK where it was needed, but then I would face the problems presented above and the code would get really messy. As a third option, it is possible to contribute to, or branch, the provided DHIS Tracker app that is currently being developed. As of 10. October 2014 (revision 172), it is a good skeleton that already has much of the functionality there, it just needs the business logic that presents the end-user-data, like the forms and the visit schedule. Anyway, this is still a working project and the mentioned functionality may be added at any time.

B.2 Problems

Below I will present the concerns, the problems that may occur and a list of the pros and cons for all solutions.

Disease Tracker

Pros

- It is a working (online) solution.
- Since it is my project, I know the code and the style of coding
- Faster short term development

Cons

- No offline support at the moment
- No guarantee that it will always support the newest version of DHIS
- Lack of functionality compared to the DHIS Tracker application

DHIS Tracker Android application

Pros

- Working online solution, and some offline functionality
- Guarantee of support of newer versions of DHIS as long as funding exists
- A lot of existing functionality
- Has extra layer of security with demand of HTTPS and a extra PIN-code for users

Cons

- Poor documentation
- Slow first time log in with usage of SDK
- It will take a bit of time to get into the code

DHIS Android SDK

Pros

- Guarantee of support of newer versions of DHIS as long as funding exists
- Has a lot of supporting functions that helps develop a new application faster
- Has extra layer of security with demand of HTTPS and functionality for extra PIN-code for users

Cons

- Poor documentation
- Slow first time log in
- Need to start from scratch

Of the pros and cons listed for every solution we can see that the DHIS Tracker Android application is the one with most pros, but the fact that it is someone else project makes it difficult. We would need assistance from the mobile team to get settled into the code and the style of coding. If we should choose to take advantage of the existing code from the DHIS Tracker Android application, we should branch their project and adapt it to the Zimbabwean context. The current application scope is too wide and tries to cover too much, and maybe it is more than Zimbabwe actually needs. It may be a better solution to build a new application, utilizing the DHIS Android SDK, specialized to the Zimbabwean context and their needs. It may take some time settling into the SDK with the poor documentation, and we would need some assistance from the developers. After that bump, I think that the development would be much faster and the scope may be smaller than the DHIS Tracker application. To feel ownership to an application may also be a factor to rapid development. At the moment no one is using the DHIS Android SDK, so we will be the first users. This may have positive and negative effects such as bugs or security holes. On the other hand, we will be the only users and we can use that as leverage to get the necessary changes that we want. The easiest way would be to continue on the Disease Tracker-project and develop it further. It is currently targeting the DHIS 2.16 and with the new changes introduced in the 2.17, it may not support the newest versions of DHIS. Zimbabwe looks at this as a long term project, and it would be beneficial to always support the newest versions of DHIS.

It also lacks the offline support, as the SDK has. The offline support is a crucial functionality, as the health workers do not have a stable Internet connection while going into the fields. Of course, it is possible to develop this functionality our self, but it will take some time. Another important functionality is to keep the initial design of the forms so that the health workers are familiar with the electronic forms as they would be with the paper-based forms. This functionality do we possess.

B.3 Conclusion

I think that what we gain more functionality with less effort utilizing the SDK, but the development would be a bit slow short term. After we get familiar with the SDK and its advantages, we will pick up speed rapidly. Personally, I think it is best to build a new application, rather than branch someone else project. I think that to feel ownership to the project is important and we can structure our code how we want it, even though we have some boundaries through the SDK. We will need some assistance from the developers, since the documentation is poor. At the moment we are the only users of the SDK, so that means that we have their full attention.

Appendix C

Appendix: The recommendation plan

The recommendation that lists three approved tablets is listed and discussed below:

	Samsung Galaxy Tab 4	Google Nexus 7	Sony Xperia Tablet Z
Screen Resolution	720p	1080p	1080p
Physical Size (Inches)	8	7	10.1
Battery (mAh)	4450	3950	6000
LTE(4G)	Yes	Yes	Yes
GPS	Yes (but no A-GPS)	Yes	Yes
Android OS version	v. 4.4.2	v. 5.0	v. 4.4.4
Water & Dust resistance	No	No	Yes

Actually we do not need Full HD resolution, the screen will use more battery. I think that HD ready(720p) is enough Physical size. The app is flexible so it should work on all screen sizes. I've been testing on a Nexus 7 emulator and it works nice. I guess it would also work nice on larger devices. Sony has the biggest battery, but also the biggest screen and a high screen resolution so it might not be the most efficient. Nexus has small screen, smallest battery and high screen resolution. I think that Samsung may be the best choice here with medium screen, resolution and medium battery capacity. All the devices supports GPS according to my sources. However, Samsung do not support A-GPS. As of today Android 5 MIGHT have some bugs since it is really new. The safe choice, today, would be Android 4.x.x Sony is the only that is water and dust resistance, which could be beneficial. For me it is between Sony and Samsung. I don't know how easy it is to obtain accessories for these devices, like keyboard, some protection and an extra battery supply, but I guess it won't be that hard to find.

Bibliography

- AbouZahr, Carla and Ties Boerma (2005). 'Health information systems: the foundations of public health'. In: *Bulletin of the World Health Organization* 83.8, pp. 578–583.
- Baskerville, Richard L (1999). 'Investigating information systems with action research'. In: *Communications of the AIS* 2.3es, p. 4.
- Baskerville, Richard L and A Trevor Wood-Harper (1996). 'A critical perspective on action research as a method for information systems research'. In: *Journal of Information Technology* 11.3, pp. 235–246.
- Baskerville, Richard and A Trevor Wood-Harper (1998). 'Diversity in information systems action research methods'. In: *European Journal of information systems* 7.2, pp. 90–107.
- Braa, Jørn, Ole Hanseth et al. (2007). 'Developing health information systems in developing countries: the flexible standards strategy'. In: *Mis Quarterly*, pp. 381–402.
- Braa, Jørn, Eric Monteiro and Sundeep Sahay (2004). 'Networks of action: sustainable health information systems across developing countries'. In: *Mis Quarterly*, pp. 337–362.
- Braa, Jørn and Sundeep Sahay (2012). *Integrated Health Information Architecture: Power to the Users: Design, Development and Use*.
- Braa, Kristin and Richard Vidgen (1999). 'Interpretation, intervention, and reduction in the organizational laboratory: a framework for in-context information system research'. In: *Accounting, Management and Information Technologies* 9.1, pp. 25–47.
- Creswell, John W (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Davison, Robert, Maris G Martinsons and Ned Kock (2004). 'Principles of canonical action research'. In: *Information systems journal* 14.1, pp. 65–86.
- Foster, Chris and Richard Heeks (2013). 'Innovation and scaling of ICT for the bottom-of-the-pyramid'. In: *Journal of Information Technology* 28.4, pp. 296–315.
- Garrib, Anupam et al. (2008). 'An evaluation of the district health information system in rural South Africa'. In: *SAMJ: South African Medical Journal* 98.7, pp. 549–552.
- Hanseth, Ole (2002). 'From systems and tools to networks and infrastructures- from design to cultivation. Towards a theory of ICT solutions and its design methodology implications'. In: *Unpublished manuscript*.

- Hanseth, Ole et al. (2006). 'Reflexive standardization: Side effects and complexity in standard making'. In: *Mis Quarterly*, pp. 563–581.
- Heeks, Richard (2002a). 'e-Government in Africa: Promise and practice'. In: *Information Polity* 7.2, pp. 97–114.
- (2002b). 'Information systems and developing countries: Failure, success, and local improvisations'. In: *The information society* 18.2, pp. 101–112.
- Heeks, Richard et al. (2003). *Most egovernment-for-development projects fail: how can risks be reduced?* Institute for Development Policy and Management, University of Manchester Manchester.
- Heeks, Richard (2006). 'Health information systems: Failure, success and improvisation'. In: *International journal of medical informatics* 75.2, pp. 125–137.
- Kaplan, Warren A (2006). 'Can the ubiquitous power of mobile phones be used to improve health outcomes in developing countries'. In: *Global Health* 2.9, pp. 1–14.
- Klein, Heinz K and Michael D Myers (1999). 'A set of principles for conducting and evaluating interpretive field studies in information systems'. In: *MIS quarterly*, pp. 67–93.
- Lippeveld, Theo (2001). 'Routine health information systems: the glue of a unified health system'. In: *Keynote address at the Workshop on Issues and Innovation in Routine Health Information in Developing Countries, Potomac, March*, pp. 14–16.
- Lippeveld, Theo, R Sauerborn and C Bodart (2000). *Design and implementation of health*.
- Organization, World Health et al. (2008). 'Framework and standards for country health information systems'. In:
- Orlikowski, Wanda J and Jack J Baroudi (1991). 'Studying information technology in organizations: Research approaches and assumptions'. In: *Information systems research* 2.1, pp. 1–28.
- Rashid, Ahmed Tareq and Laurent Elder (2009). 'Mobile phones and development: An Analysis of IDRC-supported projects'. In: *The Electronic Journal of Information Systems in Developing Countries* 36.
- Roode, Dewald (2008). 'Masters Course in Critical Reading Seminar One'. In:
- Sanders, DAVID et al. (1990). 'Equity in health: Zimbabwe nine years on'. In: *Journal of Social Development in Africa* 5.1, pp. 5–22.
- Sanner, Terje Aksel, Lars Kristian Roland and Kristin Braa (2012). 'From pilot to scale: Towards an mHealth typology for low-resource contexts'. In: *Health Policy and Technology* 1.3, pp. 155–164.
- Shrestha, Laura B and Claude Bodart (2000). 'Data transmission, data processing, and data quality'. In: *Design and implementation of health information systems*, pp. 128–145.
- Soria, Adrian Manuel Arevalo (2014). 'Interoperabilitet for Helse Informasjon Systemer: Ulike arkitektoniske tilnærminger i Colombia.' In:
- Stansfield, Sally K et al. (2006). 'Information to improve decision making for health'. In:

Williams, Robin, James Stewart and Roger Slack (2005). *Social learning in technological innovation: Experimenting with information and communication technologies*. Edward Elgar Publishing.